A Comparative Study of Anadromous and Freshwater Populations of Brook Trout (Salvelinus fontinalis (Mitchill))[1]

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ABSTRACT

Anadromous and freshwater populations of *Salvelinus fontinalis* have been compared to determine the taxonomic relationship of the sea trout and brook trout. Sea trout and freshwater trout differ seasonally in coloration and flesh colour but these differences appear to be environmental in origin rather than hereditary. Freshwater trout reared to hatching at 5.5°C. had larger head parts, deeper and wider bodies, longer fins, more pectoral rays, dorsal rays, and branchiostegals but fewer scale rows and anal rays than those of common parentage reared at 0.9°C. Sea trout and freshwater trout from the same river differ less in body form than trout of common parentage reared at different temperatures and less than four populations of freshwater trout. Differential development of the secondary sexual characteristics accounts for most of the differences in body form between sea and freshwater trout. Sea trout and freshwater trout from different rivers reared under the same conditions differed less in body form than any of the other populations compared. Sea and freshwater trout did not differ significantly in any of the meristic structures counted. Seasonal differences in weight-length relationship related to spawning and feeding habits were observed. Sea trout grow rapidly during the year in which they first migrate to the sea but subsequent growth is not appreciably faster than freshwater trout from the same river. Exposure of freshwater trout to sea water indicates that some could survive typical sea trout migrations. No evidence was obtained to indicate hereditary differences in migratory behaviour. Evidence available indicates that sea and freshwater trout of Moser River, Nova Scotia, constitute one taxonomic unit.

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INTRODUCTION

Numerous river systems in eastern Canada support populations of anadromous char commonly known as sea trout. Although the close affinity of the sea trout to the typical brook trout, *Salvelinus fontinalis*, has long been recognized, the exact systematic relationship has been a matter of much discussion and debate. In the present study several populations of brook and sea trout have been

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examined in an attempt to determine their systematic relationship. Observations were recorded on coloration, flesh colour, body form, meristic structures, weight-length relationship and age. Trout of common parentage reared to hatching at different temperatures were compared in order to assess the effect of this environmental factor on body form and structure. The resistance of freshwater trout to sea water was measured and some consideration was given to the migratory behaviour of different trout populations. The writer is greatly indebted for the guidance and advice of Professor J. R. Dymond who suggested the problem and supervised the work. Numerous suggestions have been gratefully received from Dr. A. G. Huntsman and Mr. H. C. White. Mr. White was particularly helpful in connection with the field work and aided greatly with the collection of materials.

The sea trout appears to have been named first by Smith whose rather inaccurate drawing entitled *Salmo canadensis* appears in Griffith's Cuvier published in 1834. This name was acceptable to Norris (1864) and Gilpin (1867), both of whom have published excellent descriptions of the sea trout, apparently from first-hand knowledge.

The sea trout was probably first described by Storer (1857) on the basis of a single specimen taken in 1849 in Red Bay, Labrador. Storer's name for this trout, *Salmo immaculatus*, is, however, preoccupied by one of the characins. Suckley (1874) and Kendall (1914) both express doubt about the validity of Storer's supposedly new species.

Suckley (1862) examined preserved specimens of trout obtained from Hudson Bay, Labrador and Newfoundland. He believed these fish constituted a new species which he named *Salmo hudsonicus*, the Hudson Bay trout.

Scott (1875) gave a rather detailed description of the sea trout based on the examination of numerous freshly caught specimens from the St. John River, Quebec. Although he believed the sea trout to be identical with the brook trout he published a drawing of the former entitled, "The silver or sea trout—*Trutta argentina* or *Trutta marina*". Hubbs (1943) designated these two names as synonomous and provisionally designated them as synonyms of *Salvelinus fontinalis hudsonicus* (Suckley).

Jordan and Evermann (1896), Kendall (1914) and Bigelow and Welsh (1925) all considered the sea trout and brook trout to be identical.

Hubbs (1926), however, believed the sea trout to be racially distinct from Michigan brook trout and designated it as a sub-species, *Salvelinus fontinalis hudsonicus* (Suckley).

THE SEA TROUT OF MOSER RIVER, NOVA SCOTIA

The major portion of the field work was carried on at Moser River, Halifax Co., Nova Scotia, principally during the summers of 1940 and 1941 and to a lesser extent in 1942 and 1943. From 1939 to 1943 during the open-water period the Fisheries Research Board's Atlantic salmon investigation maintained two-way fish traps on the main river and on Mill Brook, just above the head of tide (Figure 1). These traps provided information on the movements of sea trout to

and from the sea and made possible the more-or-less positive separation of sea trout and freshwater trout.

White has made a rather detailed life-history study of the Moser River sea trout, and the following account has been taken largely from his published papers (1940, 1941 and 1942).

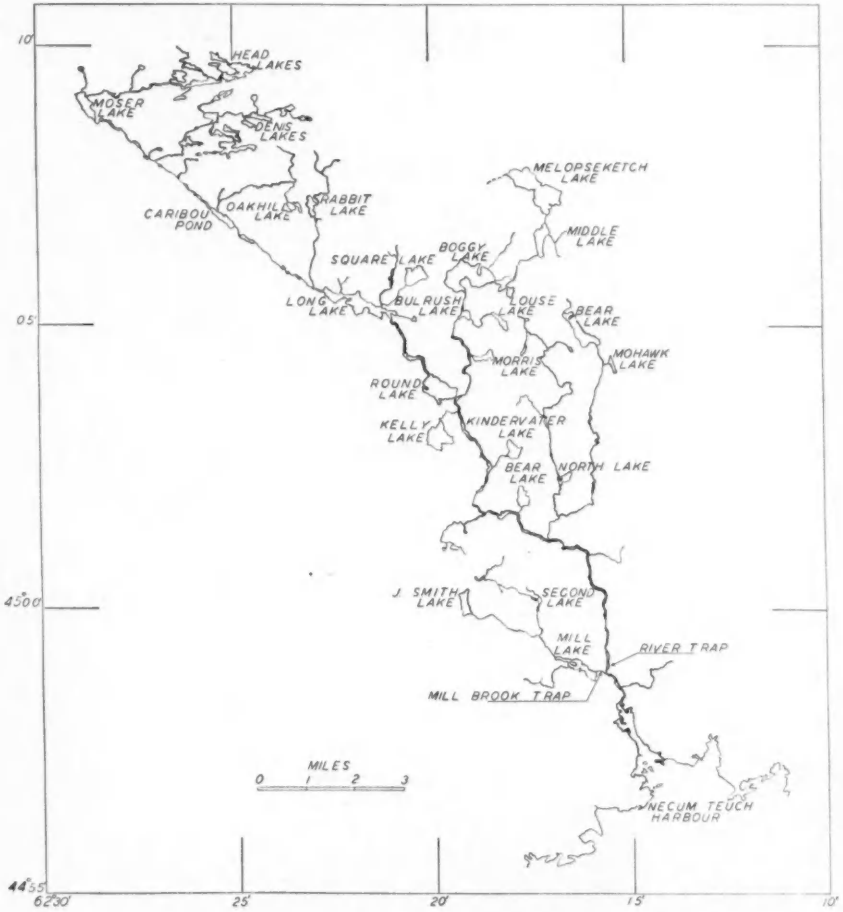

FIGURE 1. Outline map of Moser River, Halifax Co., Nova Scotia.

In spawning habits and early life in the stream the sea trout do not differ appreciably from the freshwater trout. As the young trout grow they tend to move downstream from the spawning areas into deeper water and may be taken in stillwaters and lakes during their second and third years.

The sea trout descend to the sea in April, May and early June, the "run" being composed of three groups as follows: (1) Smolts—small trout that are migrating for the first time and are similar in size and general appearance to Atlantic salmon smolts. Most (79.4 per cent) of these fish are in their third year, averaging 170 mm. total length. The remainder are in their fourth year and average 197 mm. in length. (2) Kelts—larger trout which have spawned the previous fall. (3) Immature large trout—sexually immature large fish which have not spawned the previous fall and are migrating to the sea for the second time.

The descending trout apparently move out of the inner estuary rather quickly. During May, June and early July they have been caught in the sea, four to five miles east or west of Moser River, along the typical boulder-lined, wave-swept shore. Here they rove up and down close to shore in small schools of 5 to 20 fish swimming rapidly but erratically. These trout have now acquired a heavy silver coating of guanin which renders them quite distinct in appearance from the freshwater trout caught in Moser River at this time.

Tagging experiments (White, 1941) indicate that on the average these trout remain in salt water for about two months, the majority returning to the river during July, a few, however, ascending during the latter half of June and throughout August.

Observations by the writer indicate that sea trout on re-entering the river virtually cease feeding. Of 136 fresh-run trout, 76 contained no food, 16 were practically empty, 16 contained remains of marine food, chiefly fish, and 28 contained very small amounts of freshwater organisms, chiefly insects. Of 97 sea trout taken in the stillwaters during August and September, 47 were completely empty, 27 contained very small amounts of food and 23 had stomachs partially filled.

As the season advances the sea trout proceed up stream several miles and congregate in the stillwater sections of the river where they may be caught in considerable numbers during August and September. Spawning occurs in the small streams during October.

SPECIMENS AVAILABLE FOR STUDY. Throughout this paper the term "sea trout" is used to designate anadromous trout whether taken in the sea, migrating to or from the sea or taken in fresh water some time after their return from the sea. The term "freshwater trout" is applied to those individuals of migratory size which apparently have never migrated to the sea.

In the Moser River system the identification of trout as sea or freshwater trout was greatly facilitated by the operation of two-way fish traps on Mill Brook and the main river just above the head of tide. Trout caught below or passing through these traps were accepted almost invariably as sea trout. White (1940, 1941) has shown that in this river system the seaward migration is virtually complete by the end of May and few returning sea trout ascend above the traps before the 1st of July. Trout of migratory size captured above the traps during the month of June were, therefore, considered to be freshwater trout. During July, August and September when both sea and freshwater trout were

present in the river system their separation was attempted on the basis of slight, irregular differences in body form, coloration, flesh colour, pattern of scale growth and size. Some individuals caught at this time lacked the adipose fin which identified them as sea trout so marked 2 to 5 months earlier as they descended through the Mill Brook trap. In spite of careful examination of each specimen caught during these months it was found that 148 individuals could not be classified with any degree of certainty as either sea or freshwater trout. These individuals have been designated as "doubtfuls" and have not been considered in the comparisons of sea trout and freshwater trout. No criteria were found that would permit the separation of sea trout and freshwater trout below migratory size.

In addition to the specimens obtained in the Moser River and vicinity, trout from several other areas were examined as indicated in the appendix. Complete data were not obtained for all specimens available but throughout the paper where comparisons are made the number of specimens is shown.

COLORATION

Since differences in colour between sea and freshwater trout have been pointed out by several workers, this characteristic was given considerable attention as a possible means of distinguishing the two groups. The colour pattern of Moser River sea trout was recorded for smolts migrating to the sea, for trout caught in the sea, for fresh-run trout, and for those taken in fresh water from one to three months after their return from the sea. Several populations of freshwater trout were also examined and some sea trout were held in captivity to observe colour changes more closely. The following descriptions are based on over one thousand specimens that were examined shortly after capture.

Moser River Sea Trout

SMOLTS. As these trout migrate to the sea for the first time they are very similar in colour to the typical freshwater trout. They have, however, acquired a partial coating of guanin which render the fish somewhat silvery and partially masks the basic colour pattern. The reddish spots, found also on the brook trout, were readily observed and varied from pale orange to red. The average number of these spots on the left side of seven specimens was 8.29 with a standard error of 2.34. Three smolts which were held in wooden boxes in a small stream from May 2 to August 15 not only failed to develop the heavy coating of guanin typical of trout in the sea but tended to lose the partial coating previously acquired. By July 30 they were indistinguishable from typical freshwater trout.

TROUT IN THE SEA. Shortly after the trout enter the sea the coating of guanin becomes much thicker making the cheeks, opercula and sides of the body very silvery. The dorsal surface of the head and body is a uniform pale green with the dorsal fin the same colour, although usually mottled with grey. The silvery sides gradually blend to a pearly white along the belly. The pectoral, ventral

and anal fins are usually pure white on the smaller trout but on the larger fish they are often white and grey and tinged with pink. The caudal fin is usually dark grey with an almost black terminal band. The coloured spots are usually very pale orange and may be nearly hidden by the coating of guanin. The average number of these spots on 20 specimens was 8.75 ± 0.90 (standard error), not significantly different from the count for smolts.

FRESH-RUN TROUT. As the trout re-enter fresh water the only conspicuous change in colour is a darkening of the dorsal surface which quickly changes from pale green to a dark greenish-blue or in extreme cases almost black. The number of coloured spots which averaged 9.04 ± 0.39 for 156 specimens was not significantly greater than on either of the two preceding groups.

AUGUST AND SEPTEMBER SEA TROUT. The trout which re-enter fresh water principally during July undergo gradual colour changes. By mid-August the dorsal surface is dark brown or black and the silvery coating along the sides is greatly reduced or in some cases entirely lacking. The coloured spots become a more intense orange but are not significantly more numerous than on any of the above groups averaging 9.91 ± 0.46 on 111 specimens. The pectoral, ventral and anal fins gradually assume the white, black and orange or reddish colour typical of freshwater trout. The pure white of the lower sides becomes a pinkish band in the males and the belly tends to become grey. These colour changes were confirmed by holding three fresh-run sea trout in wooden boxes in a small stream from July 15 to September 10. By September it was impossible to distinguish sea and freshwater trout by colour alone.

Moser River Freshwater Trout

The coloration of these trout varies greatly with size, sex and habitat. In general the intensity of the colour increases with the size of the fish and the males are more highly coloured than the females. The dorsal surface of the body may vary from light olive-green to black, while the sides are generally lighter in colour. The coloured spots which vary from orange to red averaged 9.83 ± 0.42 for 181 specimens, not significantly different in number from any of the above groups of sea trout. The dorsal fin is usually olive-green, mottled with black, whereas the caudal fin is most often brownish. The pectoral, ventral and anal fins are usually white, black and orange or reddish in the larger fish. Many of the smaller females caught in fresh water during May and June were quite silvery and closely resembled the migrating sea trout smolts. The trout from the larger, clearer lakes are generally lighter in colour and more silvery than those taken in the smaller, shallower lakes and in the stillwaters. Trout taken during September in Boggy Lake, the largest lake in the river system, exhibited a considerable amount of guanin and many, particularly the females, were indistinguishable from sea trout caught in fresh water at that time. These Boggy Lake trout could not have been to sea since upstream migration into this lake is barred by an impassable falls.

First Fork Brook Freshwater Trout

The water in this brook is very clear and runs over well-washed, reddish syenite gravel and rocks. The trout which reach a maximum length of 7 to 8 inches are distinctly different in coloration from other freshwater trout examined. The dorsal surface is a light olive-green and the sides are even lighter, thus the darker parr marks are very distinct even in the larger mature fish. The lower parts of the sides and the belly are an intense orange colour and in the larger specimens the only white on the ventral surface is a small triangular patch on the throat. The coloured spots which are orange rather than red averaged 18.68 ± 0.94 for 41 specimens. This average was significantly greater (< 0.01 in all cases) than any of the averages for Moser River sea or freshwater trout. The pectoral, ventral and anal fins are white, black and vivid orange. The dorsal fin is olive-coloured and mottled whereas the caudal fin is orange.

Lake Ainslie Trout

Lake Ainslie, a relatively large, shallow lake at the headwaters of the South-west Margaree River supports a large population of trout, a few of which were examined by the writer on June 30, 1941. These trout are greenish along the back. The cheeks, opercula and sides of the body are distinctly silvery and the belly is white. The coloured spots are reddish-orange. The ventral and anal fins are usually white with some orange but no black whereas the pectoral fin although similar usually shows some black. In general the colour pattern of these fish is very similar to sea trout and in fact it is believed locally that they are sea trout. The evidence available, however, indicates that these trout do not migrate to the sea (Huntsman, 1938).

Distinction of Sea Trout and Freshwater Trout on the Basis of Colour

Hubbs (1926, 1947) believes that the sea trout of the Cascapedia River, Quebec, are racially distinct from typical Michigan brook trout, certain average differences persisting in offspring reared in Michigan under approximately identical conditions. The offspring of Cascapedia trout were said to be duller in colour and more silvery, with smaller, paler coloured spots and less intense red on the lower fins. That two such widely separated trout populations should show hereditary differences in colour pattern is not surprising. Similar differences should possibly be anticipated when other widely separated or otherwise segregated populations are reared under identical conditions. For example, the striking differences in coloration between First Fork Brook trout and the other populations of freshwater trout examined may well be in part hereditary. Such differences as demonstrated by Hubbs do not, however, appear to be related to the sea running habit per se. Although Moser River sea and freshwater trout show certain seasonal differences in coloration, the evidence available indicates that these differences are not hereditary but are the result of environmental differences.

Flesh Colour

Observations were recorded on the flesh colour of 531 Moser River trout to determine whether sea trout and freshwater trout could be distinguished on this basis. Although all gradations of flesh colour from white to deep orange or red were observed the individual fish were assigned to one of four categories in recording the data. To express average colour values, these four categories, white, yellow, orange and deep orange were given the numerical values of 0, 1, 2 and 3 respectively. Since flesh colour varied with size the data are arranged in five centimetre standard length groups, as shown in Table I. As may be seen from this table, fresh-run sea trout tend on the average to have more intensely

Table I. The flesh colour of Moser River freshwater trout and sea trout. The numbers 0, 1, 2 and 3 are equivalent to white, yellow, orange and deep orange respectively.

SL	Freshwater trout						Fresh-run sea trout						August and September sea trout					
cm.	*n*	0	1	2	3	$\bar{x}$	*n*	0	1	2	3	$\bar{x}$	*n*	0	1	2	3	$\bar{x}$
10 – 15	53*	30	21	2	0	0.5	5**	4	0	1	0	0.4						
15 – 20	117	2	67	40	8	1.5	27	1	6	5	15	2.3	55	1	18	36	0	1.6
20 – 25	44	0	4	18	22	2.4	87	0	0	10	77	2.9	40	0	4	31	5	2.0
25 – 30	11	0	0	5	6	2.5	55	0	0	0	55	3.0	15	0	0	11	4	2.3
30 +							14	0	0	0	14	3.0	4	0	0	4	0	2.0
	225	32	92	65	36		188	5	6	16	161		114	1	22	82	9	

*This group may include some young sea trout.
**Sea trout smolts migrating to salt water. Four additional smolts retained in fresh water for 2½ to 3½ months and fed earthworms, all had white flesh when examined at an average SL of 14.8 cm.

coloured flesh than freshwater trout of comparable size. This difference is less pronounced among the larger fish, and large trout from Boggy and Bulrush Lakes had flesh of a deeper colour than that observed for any sea trout. Apparently the flesh colour of sea trout tends to diminish as they remain in fresh water and by August and September was less intense than that of freshwater trout taken in late May and June.

It is concluded from these observations that Moser River sea and freshwater trout cannot be distinguished on the basis of flesh colour.

RELATIVE SIZE OF BODY PARTS

To determine whether or not sea and freshwater trout could be distinguished consistently on the basis of body form a series of 22 body measurements was made on a large fraction of the trout available for study. These measurements were made on the left side of the fish with needle-pointed

dividers, or in the case of body depth and width with outside calipers, and a steel rule graduated in millimetres. Since many of the fish examined were small, measurements were estimated to 0.1 mm.. Most of the fish were measured within a few hours of capture and the majority of the remainder after only a few days in formalin. No attempt has been made therefore to correct for the slight, irregular changes associated with short-term preservation. Of the 22 measurements originally recorded only the following ten are presented for consideration in this paper.

Standard length (SL)—Tip of snout to end of vertebral column.
Snout length (Sn)—Tip of snout to anterior margin of eyeball.
Eye diameter (E)—Diameter of eyeball in an anterior-posterior direction.
Post-orbital length of head (PO)—Posterior margin of eyeball to posterior margin of operculum, exclusive of opercular flap.
Length of upper jaw (UJ)—Tip of snout to posterior end of maxillary.
Body depth (D)—Greatest body depth measured just anterior to dorsal fin.
Body width (W)—Greatest body width measured just anterior to dorsal fin.
Height of dorsal fin (DH)—Base of dorsal fin to tip of longest ray.
Height of anal fin (AH)—Base of anal fin to tip of longest ray.
Length of pectoral fin (PL)—Insertion of pectoral fin to posterior tip.
Length of ventral fin (VL)—Insertion of ventral fin to posterior tip.

The Effect of Early Developmental Temperature on the Relative Size of Body Parts

During the course of this investigation an opportunity was afforded through the kindness of Dr. A. H. Leim, to examine two lots of brook trout reared at different temperatures throughout their embryonic period. Since these two lots were the progeny of a single pair of adults, any significant differences in body form can be ascribed to temperature effects. Such a measure of the effects of a single environmental factor would assist in the evaluation of differences observed between natural trout populations.

The single pair of 12-inch adult trout was obtained from Lake Utopia, Charlotte Co., New Brunswick. These were stripped November 22, 1939, and the fertilized eggs divided into two equal lots, which were maintained at different temperatures until hatching was completed. The temperature and development history of these two lots were as follows:

	A-lot	*B-lot*
Number fertilized eggs	240	240
Hatching period	February 5 to 28, 1940	May 30, to June 28, 1940
Number hatched	216	96
Average water temperature to end of hatching period	5.5°C.(5.0 to 6.6)	0.9°C.(0.6 to 1.3)
Yolk sacs absorbed	April 19, 1940	August 26, 1940
Killed for study	August 19, 1941	November 12, 1941
Number available for study	183	50

When each lot of trout had absorbed their yolk sacs they were transferred to rearing ponds where no attempt was made to control temperatures. Consequently from April 19, 1940, to August 26, 1940, the A-lot trout were maintained at temperatures from 2°C. to 15°C. higher than the B-lot. After August 26, 1940, the two lots were reared under identical conditions.

From the 183 A-lot survivors a random sample of 50 was drawn for comparison with the 50 B-lot trout available. Three of the B-lot trout, however, were found to have abnormal vertebral columns and have not been included in the comparisons. Since no differences in body form associated with sex could be demonstrated in these small trout the two sexes have been considered together. In order to present the rather voluminous data, the trout were arranged in groups of five according to standard length. The average size of the body parts measured is listed for these length groups in the appendix Table XIII. In comparing the two lots the individual measurements were first converted to logarithms and the equations describing the linear relationship between log standard length and and log part length determined for each lot by the method of least squares. These equations listed below were then tested for differences in slope and adjusted means using the analysis of covariance method as described by Snedecor (1946).

	A-lot	*B-lot*
Sn	= 1.203 SL—1.547	= 0.967 SL—1.089
E	= 0.581 SL—0.326	= 0.468 SL—0.166
PO	= 0.916 SL—0.721	= 0.928 SL—0.755
UJ	= 1.003 SL—0.839	= 0.928 SL—0.722
D	= 1.139 SL—0.939	= 0.917 SL—0.543
W	= 1.163 SL—1.099	= 0.986 SL—0.776
DH	= 0.834 SL—0.526	= 0.754 SL—0.440
AH	= 1.045 SL—0.957	= 0.934 SL—0.796
PL	= 0.746 SL—0.305	= 0.737 SL—0.304
VL	= 0.940 SL—0.748	= 0.818 SL—0.539

The average size of each characteristic in mm. corresponding to a standard length of 100 mm. has been calculated from these equations as follows:

	A-lot	*B-lot*	*difference A–B*	*Percentage difference*
Sn	7.23	7.00	+0.23	3.3
E	6.86	5.89	+0.97	16.5
PO	12.91	12.62	+0.29	2.3
UJ	14.69	13.61	+1.08	7.9
D	21.83	19.54	+2.29	11.7
W	16.87	15.70	+1.17	7.5
DH	13.87	11.69	+2.18	18.7
AH	13.58	11.80	+1.78	15.1
PL	15.38	14.79	+0.59	4.0
VL	13.55	12.50	+1.05	8.4

Significant differences ($P<.01$) in adjusted means were found for all of the characteristics considered, the trout reared at higher temperatures consistently having relatively larger body parts. The average percentage difference for all 10 characteristics was 9.5 per cent. Only snout length, body depth and width showed significant differences in slope. Martin (1949) demonstrated similar differences in body form in rainbow trout, *Salmo gairdneri*, reared at different temperatures. The rather striking differences in the relative size of some of the characteristics studied indicates the need for caution in the interpretation of similar differences between natural trout populations.

The Relative Size of Body Parts of Moser River Sea and Freshwater Trout

In order to compare the relative size of the body parts of Moser River sea and freshwater trout the data were first arranged in groups of ten according to standard length, with the sexes considered separately. Since sea trout taken during August and September differed somewhat from fresh-run specimens they have been treated separately. For each length group the average size of the various characteristics measured is presented in the appendix, Tables XIV, XV and XVI. These averages were transferred to logarithms and the equations listed in Table II describing the straight-line relationship between log standard

Table II. Equations describing the linear relationship between log body part length and log standard length of Moser River sea trout and freshwater trout. Calculated from data of Tables XIV, XV and XVI.

	Freshwater trout	Fresh-run sea trout	Aug.-Sept. sea trout
Males			
Sn	= 1.225SL − 1.674	= 1.204SL − 1.654	= 1.314SL − 1.886
E	= 0.811SL − 0.825	= 0.678SL − 0.557	= 0.640SL − 0.454
PO	= 1.028SL − 0.935	= 0.995SL − 0.875	= 0.990SL − 0.846
UJ	= 1.180SL − 1.220	= 1.138SL − 1.179	= 1.177SL − 1.247
D	= 0.992SL − 0.624	= 1.260SL − 1.259	= 1.204SL − 1.139
W	= 0.852SL − 0.571	= 1.033SL − 0.974	= 0.984SL − 0.893
DH	= 1.030SL − 0.960	= 0.854SL − 0.587	= 0.796SL − 0.426
AH	= 0.992SL − 0.869	= 0.911SL − 0.718	= 0.873SL − 0.596
PL	= 1.114SL − 1.052	= 1.014SL − 0.876	= 1.025SL − 0.855
VL	= 1.077SL − 1.072	= 0.967SL − 0.870	= 0.902SL − 0.686
Females			
Sn	= 1.179SL − 1.607	= 1.098SL − 1.438	= 1.115SL − 1.463
E	= 0.767SL − 0.739	= 0.704SL − 0.627	= 0.599SL** − 0.364
PO	= 1.065SL − 1.041	= 0.982SL* − 0.854	= 0.974SL** − 0.821
UJ	= 1.080SL − 1.044	= 1.059SL − 1.027	= 0.986SL* − 0.843
D	= 0.959SL − 0.569	= 1.211SL** − 1.152	= 1.109SL** − 0.924
W	= 0.828SL − 0.511	= 1.044SL** − 0.998	= 1.116SL** − 1.187
DH	= 0.888SL − 0.663	= 0.917SL − 0.752	= 0.860SL − 0.593
AH	= 0.944SL − 0.777	= 0.968SL − 0.862	= 0.894SL − 0.666
PL	= 1.024SL − 0.873	= 0.997SL − 0.846	= 0.949SL − 0.700
VL	= 0.982SL − 0.887	= 0.967SL − 0.885	= 0.933SL − 0.775

*Slope differs from freshwater trout at 5% level.
**Slope differs from freshwater trout at 1% level.

length and log part length calculated by the method of least squares. The average body-part lengths corresponding to a standard length of 200 mm. have been calculated from these equations and are given in Table III.

It is evident from Table III that older male trout differ consistently from the females in having larger head parts, longer fins and a slightly deeper but more compressed body. These differences which develop at the onset of sexual maturity may be referred to as secondary sexual characteristics. With regard to sexual maturity and spawning condition each of the three groups of trout considered is quite heterogeneous. Examination of 272 sea trout ranging in standard length from 15 to 40 cm., taken principally from mid-July to mid-September, indicated that 36 per cent would not spawn that fall. Of those below 24 cm. in length (166) 56 per cent would not spawn. The sea trout run therefore includes a large proportion of immature fish, a considerable proportion of virgin trout that are in their first spawning run, and relatively few re-spawners. Sea trout taken during August and September would include some specimens approaching the spawning condition. Since the freshwater trout were taken principally in late May and June, their state of maturity could not be determined by superficial examination of the gonads. It is believed, however, from general observations on the spawning of freshwater trout that this group was made up principally of trout which had spawned the previous autumn. These differences in sexual maturity and spawning conditions are reflected in the secondary sexual characteristics, these being most marked in the freshwater trout, intermediate in the August and September sea trout and least evident in the fresh-run sea trout. Considering the calculated averages for all ten characteristics as listed in Table III, male freshwater trout totalled 15.5 mm. larger than the females, male August and September sea trout 9.9 mm. larger than the females and male fresh-run sea trout 7.1 mm. larger than the females. On the basis of development of secondary sexual characteristics, August and September sea trout are therefore more comparable with the freshwater trout than are the fresh-run sea trout. Since changes in the relative sizes of body parts associated with sexual maturity are less marked among the females, these alone have been tested for differences in slopes and adjusted means by the analysis of covariance.

As may be seen in Table III male freshwater trout differ consistently from male fresh-run sea trout in having larger head parts and fins and deeper but more compressed bodies, the average percentage differences for all ten characteristics being 8.3 per cent. For seven of the ten characteristics considered, the male freshwater and August and September sea trout show similar but less marked differences, the average percentage difference for all ten characteristics being 3.2 per cent.

For all characteristics measured, the female freshwater and fresh-run sea trout differ in the same direction as the males but to a lesser degree, the average percentage difference being 5.2 per cent. When, however, the female freshwater trout are compared with August and September female sea trout the differences are either reversed or greatly reduced for nine of the characteristics, the average percentage difference being only 1.8 per cent. Body depth was the only charac-

TABLE. III. Calculated average body part length in millimetres for 200 mm. standard length. Moser River male and female sea and freshwater trout.

	Males					Females				
	1 Freshwater trout	2 Fresh-run sea trout	3 Aug. Sept. sea trout	1–2 Difference	1–3 Difference	1 Freshwater trout	2 Fresh-run sea trout	3 Aug.-Sept. sea trout	1–2 Difference	1–3 Difference
Sn	13.96	13.06	13.74	+ 0.90	+ 0.22	12.76	12.25	12.65	+ 0.51*	+ 0.11
E	10.99	10.07	10.45	+ 0.92	+ 0.54	10.62	9.84	10.33	+ 0.78*	+ 0.29*
PO	26.92	25.94	27.04	+ 0.98	− 0.12	25.64	25.47	26.30	+ 0.17	− 0.66*
UJ	31.26	27.48	28.91	+ 3.78	+ 2.35	27.61	25.70	26.67	+ 1.91*	+ 0.94*
D	45.50	43.65	42.76	+ 1.85	+ 2.74	43.45	43.05	42.46	+ 0.40	+ 0.99
W	24.43	25.29	23.50	− 0.86	+ 0.93	24.77	25.35	24.04	− 0.58	+ 0.73
DH	25.70	23.88	25.47	+ 1.82	+ 0.23	23.99	22.80	24.32	+ 1.19*	− 0.33
AH	25.88	23.88	25.88	+ 2.00	0	24.83	23.17	24.60	+ 1.66*	+ 0.23
PL	32.43	28.64	31.84	+ 3.79	+ 0.59	30.41	28.05	30.48	+ 2.36*	− 0.07
VL	25.47	22.65	24.55	+ 2.82	+ 0.92	23.60	21.88	23.50	+ 1.72*	+ 0.10

*Adjusted mean body part lengths of sea trout and freshwater trout differ significantly ($P < .01$).

teristic that showed a greater but non-significant difference. Only three characteristics, eye, post-orbital head length and upper jaw showed significant differences, the post-orbital difference being in a reverse direction. Since post-orbital head length does not show a consistent difference and since the differences in eye diameter and length of upper jaw, which are equivalent to 2.8 per cent and 3.5 per cent, are considerably less than corresponding differences found in the two lots of trout reared under different temperatures, it is concluded that Moser River sea trout and freshwater trout do not differ hereditarily in any of the characteristics measured.

Progeny of Sea Trout and Freshwater Trout Reared under the Same Conditions

In the course of the trout investigation conducted at Ellerslie, P.E.I. by the Fisheries Research Board eggs have been obtained from known Ellerslie Brook sea trout and from Eliot River, P.E.I., trout. Although Eliot River no doubt originally supported a population of sea trout, a dam which prevents upstream migration has been maintained near the head of tide for at least 20 years. Thus the population of trout above the dam has been maintained for a number of generations by the spawning of non-sea-run individuals. During the summer of 1947 trout were obtained from both streams and transferred to the Southport, P.E.I., hatchery where the eggs were hatched and reared for some time in parallel troughs which had a common water supply. They were then transferred to the Cardigan, P.E.I., hatchery where they were reared to fingerlings in circular ponds with a common water supply. Through the kindness of Dr. M. W. Smith samples of 35 fingerling trout from each group taken September 1, 1948, just before planting, were made available for study.

For each stock the data were arranged in groups of five according to standard length and the average size of the characteristics measured determined for each length group as given in the appendix (Table XVII). These averages were then analysed to determine and test the equations relating log standard length and log body part length. From these equations listed in Table IV the

Table IV. Equations describing the linear relationship between log part length and log standard length of Ellerslie Brook and Eliot River trout. Calculated from data of Table XVII.

	Ellerslie	Eliot
Sn	= 0.882SL − 0.965	= 0.991SL − 1.155
E	= 0.667SL − 0.557	= 0.405SL* − 0.108
PO	= 0.938SL − 0.740	= 1.075SL − 0.964
UJ	= 0.924SL − 0.750	= 0.959SL − 0.813
D	= 0.956SL − 0.565	= 0.979SL − 0.605
W	= 0.961SL − 0.740	= 1.008SL − 0.811
AH	= 0.784SL − 0.366	= 0.822SL − 0.412
PL	= 0.803SL − 0.417	= 0.856SL − 0.504
VL	= 0.953SL − 0.744	= 0.925SL − 0.697

*Slope differs from Ellerslie trout at 5% level.

TABLE V. Calculated average body part length in mm. for 47 mm. standard length Ellerslie Brook and Eliot River trout.

	Ellerslie Brook	Eliot River	Diff.	Diff.
	mm.	*mm.*	*mm.*	%
Sn	3.24	3.18	− .06	1.9
E	3.61	3.71	+ .10**	2.8
PO	6.73	6.81	+ .08	1.2
UJ	6.24	6.17	− .07	1.1
D	10.79	10.76	− .03	0.3
W	7.36	7.48	+ .12	1.6
AH	8.81	9.16	+ .35*	4.0
PL	8.43	8.45	+ .02	0.2
VL	7.06	7.08	+ .02	0.3

*Adjusted means differ at 5% level of significance.
**Adjusted means differ at 1% level of significance.

average body part lengths corresponding to the overall average SL of 47 mm. were calculated as listed in Table V.

Dorsal heights were not compared, as all of the trout in the Ellerslie Brook sample showed evidence of recovery from an infection in this fin. Of the nine characteristics measured, only eye diameter showed a significant difference in adjusted means at the 1 per cent level and anal height at the 5 per cent level. None of the equations differed in slope at the 1 per cent level and only one (eye diameter) differed at the 5 per cent level. The average percentage difference for all nine characteristics was only 1.5 per cent as compared to the corresponding average difference of 9.5 per cent between the two lots of trout reared at different temperatures.

The difference in eye diameter may represent a hereditary difference in these two stocks but as Martin (1949) has pointed out, caution must be exercised in interpreting differences based on samples composed of single age groups. The relationship between standard length and body part length as determined by these single age groups does not represent the true ontogenetic relative growth picture. The Ellerslie Brook trout which averaged 45.1 mm. SL as compared to the 49.2 mm. average for Eliot River trout might have attained the same relative eye size had they been allowed to grow to the same length.

DIFFERENCES AMONG FOUR WIDELY SEPARATED POPULATIONS OF FRESHWATER TROUT

During the course of the investigation samples of trout were obtained from the following rather widely separated brooks, First Fork Brook, Margaree River, Cape Breton, N.S., Bezanson's Brook, Moser River, N.S., Rocky Brook, Shubenacadie Lake, N.S., and Bocabec Brook, Charlotte Co., N.B. None of these small streams is characterized by a run of sea trout and all of the specimens collected were typical freshwater trout in every respect.

Since some of the larger males and females in each collection were mature, the sexes were segregated for study and the specimens arranged in standard

TABLE VI. Equations describing the linear relationship between log body part length and log standard length of male and female freshwater trout from four widely separated brooks. Calculated from data of Tables XVIII and XIX.

	Bocabec Brook	Bezanson's Brook	Rocky Brook	First Fork Brook
Males				
Sn	= 1.336SL − 1.767	= 1.212SL − 1.590	= 1.044SL − 1.243	= 1.096SL − 1.399
E	= 0.736SL − 0.614	= 0.714SL − 0.601	= 0.725SL − 0.622	= 0.729SL − 0.667
PO	= 1.167SL − 1.186	= 1.074SL − 0.984	= 0.989SL − 0.842	= 1.064SL − 1.037
UJ	= 1.306SL − 1.359	= 1.185SL − 1.160	= 0.983SL − 0.816	= 1.296SL − 1.450
D	= 1.132SL − 0.876	= 0.912SL − 0.489	= 0.944SL − 0.544	= 1.109SL − 0.887
W	= 0.911SL − 0.635	= 0.982SL − 0.800	= 0.962SL − 0.760	= 1.003SL − 0.899
DH	= 0.862SL − 0.504	= 0.821SL − 0.472	= 0.854SL − 0.533	= 0.852SL − 0.555
AH	= 1.032SL − 0.850	= 0.789SL − 0.409	= 0.893SL − 0.629	= 0.946SL − 0.742
PL	= 0.970SL − 0.656	= 0.898SL − 0.534	= 0.886SL − 0.527	= 1.027SL − 0.832
VL	= 1.039SL − 0.902	= 0.860SL − 0.559	= 0.809SL − 0.481	= 1.021SL − 0.911
Females				
Sn	= 1.126SL − 1.387	= 1.150SL − 1.467	= 1.054SL − 1.265	= 1.088SL − 1.406
E	= 0.851SL − 0.851	= 0.804SL − 0.781	= 0.697SL − 0.580	= 0.838SL − 0.889
PO	= 1.014SL − 0.904	= 1.020SL − 0.908	= 0.985SL − 0.839	= 1.116SL − 1.150
UJ	= 1.109SL − 1.008	= 1.107SL − 1.044	= 1.056SL − 0.937	= 1.203SL − 1.281
D	= 1.035SL − 0.702	= 0.905SL − 0.476	= 0.980SL − 0.613	= 1.009SL − 0.674
W	= 1.217SL − 1.213	= 1.082SL − 1.005	= 1.089SL − 0.995	= 1.059SL − 1.023
DH	= 0.657SL − 0.129	= 0.754SL − 0.336	= 0.856SL − 0.546	= 0.869SL − 0.606
AH	= 1.054SL − 0.899	= 0.802SL − 0.438	= 0.935SL − 0.708	= 1.224SL − 1.323
PL	= 0.827SL − 0.390	= 0.863SL − 0.485	= 0.886SL − 0.537	= 1.034SL − 0.855
VL	= 0.834SL − 0.507	= 0.806SL − 0.469	= 0.880SL − 0.618	= 0.988SL − 0.862

length groups of approximately equal numbers as indicated in the appendix Tables XVIII and XIX. The average measurements were then transferred to logarithms and the equations given in Table VI calculated by the method of least squares. From these equations the average body part size corresponding to a standard length of 100 mm. was calculated for both sexes in each sample as indicated in Table VII.

TABLE VII. Calculated average body part length in mm. for 100 mm. standard length male and female freshwater trout from four widely separated brooks.

	Sn	E	PO	UJ	D	W	DH	AH	PL	VL
Males										
Bocabec Brook	8.04	7.21	14.06	17.91	24.43	15.38	16.60	16.37	19.23	15.00
Bezanson's Brook	6.82	6.71	14.59	16.22	21.63	14.59	14.79	14.76	18.28	14.49
Rocky Brook	7.00	6.73	13.68	14.79	22.08	14.59	14.96	14.35	17.58	13.71
First Fork Brook	6.21	6.18	12.33	13.87	21.43	12.79	14.09	14.13	16.67	13.52
Females										
Bocabec Brook	7.33	7.10	13.30	16.22	23.33	16.63	15.31	16.18	18.37	14.49
Bezanson's Brook	6.81	6.71	13.55	14.79	21.63	14.42	14.86	14.66	17.42	13.90
Rocky Brook	6.97	6.52	13.52	14.96	22.23	15.24	14.66	14.52	17.18	13.93
First Fork Brook	5.89	6.12	12.08	13.34	22.08	12.45	13.55	13.34	16.33	13.00

Almost without exception the Bocabec trout have the largest and First Fork trout the smallest body characteristics. Bezanson's Brook and Rocky Brook trout are very similar and their characteristics are intermediate between those of Bocabec and First Fork trout. No doubt a large part of the differences demonstrated is related to differential development of the secondary sexual characteristics. The Bocabec sample which was taken September 23, 1940, included 18 mature specimens (60 per cent) which were very close to spawning condition. Both the Rocky Brook and Bezanson's Brook samples were taken early in August, at least two months before spawning, and included only 15 per cent and 16 per cent mature specimens respectively. Although the First Fork Brook sample included the highest percentage of mature fish (77 per cent), this collection was made on July 1st, at least three months before spawning.

The average percentage difference for all characteristics measured between First Fork Brook trout and the other three populations has been calculated as follows: Bocabec Brook, males 18.4 per cent, females 17.0 per cent; Bezanson's Brook, males 9.5 per cent, females 9.9 per cent; Rocky Brook, males 7.1 per cent, females 10.2 per cent, considerably greater percentage differences than those found between Moser River sea trout and freshwater trout or between Ellerslie Brook sea trout and Eliot River freshwater trout reared under the same conditions. These data indicate quite clearly the extent to which populations of brook trout taken from rather similar habitats (small, cool, precipitous brooks) may vary in the relative size of certain body characteristics.

Distinction of Sea Trout and Freshwater Trout on the Basis of Body Form

Several workers who have considered the relationship of sea trout and freshwater trout have cited certain differences in body form. Suckley (1862) states that the sea trout has a smaller head. Morris (1864) says that the body of the sea trout is not so compressed. Gilpin, however, (1867) who appears to have been very familiar with the sea trout of Nova Scotia concluded that the sea trout was deeper and more compressed, had a more arched head, and possibly shorter fins. Hubbs (1926) who has observed progeny of the sea trout from the Cascapedia River, P.Q., reared in Michigan under similar conditions to the native trout states that second generation progeny Cascapedia trout are more terete than the natives.

As may be seen in Table III Moser River freshwater trout are deeper and more compressed than fresh-run sea trout, although these differences were not statistically significant in the females. Freshwater trout are, however, not only deeper but also wider than sea trout taken one to two months after their return from the sea. Generally, freshwater trout have larger head parts and fins as well, but these differences are greatly reduced when samples more similar in the development of secondary sexual characteristics are compared. Even smaller differences were found when immature freshwater trout and sea trout from Prince Edward Island were reared under identical conditions. In general, the differences found between Moser River sea trout and freshwater trout were

TABLE VIII. Number of branchiostegals, gill-rakers and fin rays of several trout populations.

	Branchiostegals							Gill-rakers											Ventral rays				
	8	9	10	11	12	n	$\bar{x}$	13	14	15	16	17	18	19	20	21	n	$\bar{x}$	7	8	9	n	$\bar{x}$
A-lot 5.5°C.		1	16	27	6	50	10.76			1	0	4	5	4	1		15	17.93		50		50	8.00
B-lot 0.9°C.		4	27	14	1	46	10.26		1	0	2	5	4	3	0		15	17.33	2	44		46	7.96
Moser River																							
Freshwater Trout		13	64	68	21	166	10.58		2	14	35	35	33	20	10	1	150	17.25	3	144	20	167	8.10
Sea Trout		4	75	104	24	207	10.71		1	10	31	53	42	28	6	0	171	17.36	1	193	15	209	8.07
Bocabec Brook	1	2	20	7		30	10.10	4	2	2	3	1					12	14.58	1	29		30	7.97
Bezanson's Brook			5	6		11	10.54		2	0	1	0	1				4	15.50	2	9		11	7.82
Rocky Brook		1	10	4		15	10.20			1	2	0	0	0	1		4	16.75	1	14	1	16	8.00
First Fork Brook		1	16	4		21	10.14			1	7	6	4	3			21	17.05		22		22	8.00

	Dorsal rays							Pectoral rays								Anal rays						
	10	11	12	13	14	n	$\bar{x}$	10	11	12	13	14	15	n	$\bar{x}$	9	10	11	12	13	n	$\bar{x}$
A-lot 5.5°C.		14	36			50	11.72		1	12	37			50	12.72	15	32	3			50	9.76
B-lot 0.9°C.	2	25	17			44	11.34	1	3	21	21			46	12.35	1	28	14	2	1	46	10.43
Moser River																						
Freshwater Trout	1	41	96	29		167	11.92		1	15	91	58	1	167	13.26	1	33	107	26		167	10.95
Sea Trout		40	120	50	1	211	12.06			10	136	63		209	13.25	1	47	123	38		209	10.95
Bocabec Brook		2	23	5		30	12.10		2	18	9	1		30	12.30	1	10	18	1		30	10.63
Bezanson's Brook		3	5	1		9	11.78		1	5	5			11	12.36		6	5			11	10.45
Rocky Brook	1	3	9	3		16	11.88		2	8	6			16	12.25	1	8	7			16	10.38
First Fork Brook		1	15	5	1	22	12.27			6	16			22	12.73		7	14	1		22	10.73

considerably less than those between the progeny of one pair of trout reared at different temperatures and much less than the differences found among four widely separated populations of freshwater trout. It is concluded therefore that Moser River sea and freshwater trout cannot be distinguished on the basis of body form. Moser River trout may well differ hereditarily from other widely separated populations of trout, as indeed First Fork Brook trout may so differ from Bocabec Brook trout. Extreme care should, however, be exercised in reaching conclusions based on the examination of naturally reared populations. In this group the designation of sub-species based on samples of trout reared under different conditions is an extremely doubtful practice.

MERISTIC COUNTS

Counts were made of branchiostegals, gill-rakers, dorsal, anal, pectoral and ventral fin rays, lateral line scales, and vertebrae to determine whether or not sea trout and freshwater trout could be distinguished on the basis of any of these structures. The branchiostegal count represents the total number distinguishable. All the gill-rakers on both limbs of the first gill arch were counted including rudimentary rakers sometimes present on large trout. All fin ray counts are total counts including, in the case of the dorsal and anal fins, one to three rudimentary rays at the anterior insertion. The last ray of the dorsal and anal fins, although usually divided to the base, was counted as a single ray. The lateral line scale count represents the number of scale rows passing through the lateral line, counted from the posterior margin of the head to the end of the vertebral column. In counting the vertebrae the urostyle was excluded. All paired structures were counted on the left side of the fish only.

The frequency distributions and average counts for A and B lots of trout reared at different temperatures, for Moser River sea and freshwater trout, and for four populations of freshwater trout are given in Tables VIII and IX. Since no differences could be detected between male and female trout, the sexes have not been segregated. Differences between A and B lots of trout, between Moser River sea and freshwater trout and between the four populations of freshwater trout were tested by the analysis of variance.

The A-lot trout reared at higher temperatures had more pectoral rays, dorsal rays and branchiostegals but fewer scale rows and anal rays. all of these differences being statistically significant at the 1 per cent level. The ventral ray and gill-raker counts did not differ significantly. The difference in scale rows corresponds closely with that found by Mottley (1934) for Kamloops trout reared at different temperatures.

Moser River sea and freshwater trout did not differ at the 1 per cent level in any of the structures counted and in each case the differences observed were less than those demonstrated for the two lots of trout reared at different temperatures. Vertebral counts which averaged 56.68 for 25 sea trout and 57.04 for 24 freshwater trout did not differ significantly.

The four groups of freshwater trout differed significantly ($P<.01$) only in the number of gill-rakers. The exceptionally low raker count for Bocabec

TABLE IX. Number of lateral line scales of trout reared at different temperatures and of Moser River sea and freshwater trout.

Scales	A-lot 5.5°C.	B-lot 0.9°C.	Moser River freshwater trout	Moser River sea trout
195	1			
6				
7				
8				
9				
200	1		1	
1	1			1
2	2			
3				
4		1		
5				
6	1		1	
7				
8	2			
9	2			
210	5	1		1
1	1		3	1
2	2		2	
3			1	1
4	1		1	1
5			1	1
6	1			1
7			1	
8		1	1	2
9				
220			1	2
1		1	1	3
2	1	2	1	2
3			3	1
4		1	1	3
5		1		2
6			1	4
7			1	1
8		2		1
9			2	4
230		1	1	3
1		1	1	3
2			2	1
3		1		4
4			2	1
5		1	1	3
6			1	1
7		2		
8		1		
9		1	1	
240		2		2
1		1		
2				
3			1	
n	21	21	33	50
$\bar{x}$	208.43	228.71	222.81	225.70

trout is possibly a result of the low average size (115 mm. SL) of the fish in this sample as there is some evidence to indicate that raker count increases with size in salmonoids (Foerster and Pritchard, 1934; Wilder, 1947).

On the basis of the above data it is concluded that Moser River sea trout and freshwater trout do not differ hereditarily in any of the meristic structures counted.

WEIGHT-LENGTH RELATIONSHIPS

The weight-length relationship of Moser River trout was calculated from measurements and weights of 248 fresh-run sea trout, 168 sea trout taken one to two months after their return from the sea, and of 182 freshwater trout taken during May and June. The trout were measured (standard lengths) to the nearest millimetre and weighed on a postal balance to one-tenth of an ounce. To reduce bulk the data were arranged according to standard length and average lengths and weights calculated for groups of ten trout. These averages are presented in Table X with the weights converted to grams. These averages were then converted to logarithms and the equations describing the

TABLE X. The average standard length (mm.) and weight (grams) of Moser River sea and freshwater trout in groups of 10 fish according to length.

Fresh-run sea trout		August and September sea trout		Freshwater trout	
Length	Weight	Length	Weight	Length	Weight
163	65.8	164	64.4	151	60.1
177	89.1	172	74.0	157	62.1
187	99.8	180	84.8	161	68.1
192	108.9	186	90.4	164	70.6
198	127.5	190	94.7	167	76.3
203	132.0	194	104.6	171	79.4
207	144.0	198	118.4	177	92.2
210	142.5	201	113.0	181	97.0
214	159.2	207	131.4	185	99.5
217	161.2	211	140.6	189	102.0
221	173.9	216	148.9	194	113.9
226	182.9	221	158.4	198	126.1
232	202.5	228	172.1	204	124.4
237	218.0	237	202.5	210	143.0
242	237.5	253	248.0	216	161.6
246	244.5	274	332.1	233	181.4
249	270.5	305*	459.0	248	226.8
253	265.0			257**	284.2
258	294.5			282**	340.0
264	305.5				
272	339.0				
284	395.5				
293	414.0				
313	526.0				
381*	1028.0				

*Eight specimens. **Six specimens.

log length-log weight relationship determined by the method of least squares. These equations were then tested for differences in slope and adjusted means by the analysis of covariance:

Fresh-run sea trout: log weight (grams) = 3.2117 (log SL mm.)—5.2880.
August and September sea trout: log weight (grams)=3.2128 (log SL mm.) —5.3245.
Freshwater trout: log weight (grams)=2.8526 (log SL mm.)—4.4639.

From these equations the average weights corresponding to an average standard length of 200 mm. were as follows: Fresh-run sea trout 126.5 grams, August and September sea trout 116.9 grams, freshwater trout 125.9 grams.

The regression lines for fresh-run and August and September sea trout both differed significantly ($P<.01$) in slope from the freshwater trout line. Fresh-run sea trout were slightly but not significantly heavier at a standard length of 200 mm. whereas August and September sea trout were significantly lighter at this length than freshwater trout. The low regression-coefficient for freshwater trout reflects the poor condition of the larger trout in this collection, many of which had presumably spawned the previous fall and not fully recovered at the time of sampling. The fresh-run sea trout sample which was taken about one month later was composed largely of immature trout and first spawners. The few respawners in the sample had, after one to two months in the sea, fully recovered their weights. The low average weight of August-September sea trout as compared to fresh-run sea trout is to be expected from the fact that trout returning from the sea feed to only a limited extent in fresh water.

Although certain differences in the weight-length relationship of Moser River sea and freshwater trout have been demonstrated these are related to differences in spawning and feeding habits.

AGE AND GROWTH

The approximate ages of Moser River sea trout and several populations of freshwater trout have been determined by examination of the scales. The scales are small and some, particularly those of trout from small, cool brooks and certain lakes, are difficult to read. Sea trout scales are generally easier to interpret since growth in the sea is usually associated with the formation of wide, even circuli.

The average standard lengths for different age groups have been calculated for Moser River fresh-run sea trout (235 specimens), Moser River freshwater trout (236 specimens), trout from Bezanson's Brook (31), First Fork Brook (42), Rocky Brook (42) and Bocabec Brook (29) as shown in Table XI. Similar averages calculated for sea trout taken during August and September, one to two months after their return to fresh water, did not differ significantly from those for fresh-run fish, indicating that trout leaving the sea have completed their growth for the season. The Moser River freshwater trout, however, which were taken from May 20 to June 26, when the sea trout were virtually absent from the river, had not completed their growth for the season and are

therefore not strictly comparable to the sea trout. Trout below migratory size could not usually be classified as either sea or freshwater trout but those taken from May 20 to June 26 have been included with the freshwater trout in Table XI.

Only a few trout smolts were examined by the writer, the average standard length of five of these taken May 17, 1941, in their third year being 144 mm. Hoar (1939), however, has calculated the average total (= natural tip) length of 108 Moser River smolts, taken May 3 to 11, 1939, in their third year as 170 mm., which is equivalent to a standard length of 145 mm.

TABLE XI. Average standard lengths* of trout for different age groups. Measurements in millimetres with number of specimens in parentheses. Roman numerals represent number of annuli.

	0	I	II	III	IV	V	VI
Moser River							
Freshwater trout							
May 20-June 26	39(6)	109(8)	156(51)	178(123)	224(46)	274(2)	
Fresh-run sea trout							
May 18-Aug. 4			201(94)	247(103)	274(30)	334(7)	396(1)
Bezanson's Brook							
Aug. 2-10	53(19)	103(8)	134(2)	152(2)			
First Fork Brook							
July 1		94(2)	112(21)	141(18)	168(1)		
Rocky Brook							
Aug. 10	48(26)	108(13)	178(1)	191(2)			
Bocabec Brook							
Sept. 23	57(1)	90(19)	121(9)				

*The equations describing the straight line relationship between standard length, fork length (measured from tip of the snout to the end of the shortest ray of the caudal fin) and natural tip length (measured from tip of snout-to dorsal tip of caudal fin with this fin in a "natural" position) have been calculated by the method of least squares from measurements of 380 Moser River trout ranging in standard length from 87 to 426 mm.:

Fork length (mm.) = 1.096 x Standard length (mm.)+4.4.
Natural tip length (mm.) = 1.100 x Standard length (mm.)+10.3.

Taking 145 mm. SL as the average pre-migration size of smolts in their third year, Table XI shows that those fish grow rapidly during their first summer in the sea, an average of 56 mm. During their second and third summers in the sea, growth is considerably slower, averaging only 36 mm. for these two years, not greatly different from the average growth of 34 mm. for freshwater trout of corresponding ages.

The four populations of trout from the small brooks did not differ appreciably in growth rate. Since, however, all of these trout when collected had completed a higher proportion of their season's growth than had the Moser River freshwater trout, it appears that they are slower growing, particularly during their third and subsequent years.

The differences in growth rate between sea and freshwater trout as indicated by these data are not striking, and judging by the evidence presented by Catt (1937, 1938, 1941) on the effects of transferring trout, could well be the result of environmental differences alone.

RESISTANCE TO SEA WATER

Since freshwater trout do not migrate to the sea, an attempt was made to determine whether they could survive in salt water. During the month of October, 1943, a total of 118 trout were seined from several small brooks in the vicinity of St. Andrews, N.B., and quickly transferred to concrete tanks supplied with running sea water (30‰). No attempt was made to control the water temperature which varied from 10.5° to 12.5°C. The trout which ranged in total length from 57 mm. to 286 mm. were, with one exception, typical freshwater trout. The exception, a 207 mm. immature female was taken in freshwater at the head of a tidal cove. This specimen had all of the characteristics associated with life in the sea and had probably left the tidal cove shortly before capture. Several of the trout from 115 to 151 mm. and all of those over 151 mm. except the single specimen just referred to were ripe at the time of capture. All but two of the trout died within six days. The average survival times are given in Table XII with the immature and ripe trout listed separately.

It is evident from this table that the resistance of immature trout increases with size. This relationship, however, does not appear to hold as well for the

TABLE XII. Survival time in hours of trout in 30‰ sea water at 10.5°C. to 12.5°C.

Total length	Immature trout	*n*	Av.	Mature trout	*n*	Av.
cm.						
6	6, 7, 7, 7, 8, 8, 8,	7	7.3			
7	7, 7, 8, 8, 8, 8, 9, 10, 10, 11	10	8.6			
8	7, 9, 9, 9, 10, 10, 10, 10, 11, 11, 13, 13, 14, 15, 16	15	11.1			
9	8, 10, 11, 12, 13, 14, 23	7	13.0			
10	11, 13, 13, 15, 15, 16, 17, 18, 19, 20, 21, 22, 36	13	18.2			
11	15, 16, 16, 19, 22, 24	6	18.7			
12	16, 16, 18, 19, 19, 20, 21, 52	8	22.6	15, 24	2	19.5
13	17, 20, 21, 22, 52	5	26.4	15, 22, 32, 34	4	25.8
14	16, 17, 21, 25, 27, 32, 38, 52, 61, 73	10	36.2	16, 17, 19, 22, 22, 66	6	27.0
15	39, 41, 76	3	52.0	22	1	22
16				16, 18, 20, 65	4	29.8
17				36, 61	2	48.5
18				17, 24, 39, 64	4	36.0
19				17, 18, 73	3	36.0
20				18, 39, 63, 138	4	64.5
21	194+	1		38	1	38
22						
23						
24						
25				45	1	45
26						
27						
28				356+	1	356+
29						
		85			33	

ripe trout, several of the larger specimens being less resistant than would be expected on the basis of size. Two of the trout were apparently unaffected by the sea water. The first, the 207 mm. female sea trout, was in excellent condition after 194 hours in salt water. The resistance of this specimen, the largest immature fish tested is not surprising in view of the total length-resistance time relationship shown for smaller immature trout. The other unaffected specimen, a 286 mm. ripe female, was in excellent condition after 356 hours in sea water when it was killed for examination.

The fact that small freshwater trout are unable to live in sea water is not surprising in view of the work of Huntsman and Hoar (1939) who showed that 4 cm. and 8 cm. Atlantic salmon parr died in 5 and 9 hours respectively when transferred to sea water (28‰). Since one of the trout tested lived for almost 15 days in sea water, it appears that some freshwater trout could live for considerable periods in the sea.

In these experiments the trout were subjected to greater and more abrupt changes than they would usually experience in nature. Where sea trout are abundant the inshore salinity is often below 30‰ and the rivers are usually characterized by long brackish estuaries. Many so-called sea trout may not descend beyond these estuaries and those that do would have the opportunity to become acclimated to higher salinities.

PRODUCTION AND MIGRATION IN MILL BROOK AND IN THE MAIN MOSER RIVER

During May, 1942, a total of 820 sea trout descended through the Mill Brook traps and 1,793 through the main river trap. Thus, although the main river including tributaries is almost 8 times as long as Mill Brook and has over 15 times the lake area, it produces only slightly more than twice as many sea trout.

Examination of various tributaries of both the main river and Mill Brook indicates that the main river is much superior in regard to extent and suitability of spawning beds and rearing grounds. General angling reports supported by the author's own observations indicate further that during the period when the sea trout are in salt water, angling is much better in the main river system, particularly for large trout. There is, therefore, reason to believe that the total trout production is relatively better in the main river than in Mill Brook but it appears that a higher proportion of the trout produced in the brook system migrate to the sea. These conclusions are supported by the following data on the sex ratios of sea and freshwater trout.

Sex Ratio of Sea Trout and Freshwater Trout

The sex of 435 sea trout was determined and of these 313 (72.0 per cent) were females and 122 (28.0 per cent) were males. This ratio varied only slightly for trout smolts migrating to the sea, trout caught in the sea, fresh-run trout, and trout caught one to two months after their return from the sea. No appreciable change in this ratio could be demonstrated in relation to time of migration or to the age of the trout.

Of 62 trout taken in Mill Brook between June 14 and 24, 1941, when, according to the trap at the mouth of the brook sea trout were absent from this branch, 18 (29.0 per cent) were females and 44 (71.0 per cent) were males.

From May 20 to June 18, 1941, after the run of trout to the sea was virtually over and before any returning trout had passed through the main river trap, a total of 88 trout were caught several miles above the trap in the vicinity of North, Round and Bulrush Lakes. Of these, 46 (52.3 per cent) were females and 42 (47.7 per cent) were males.

These data indicate that the sea trout run (72 per cent females) from Mill Brook forms such a high proportion of the total stock that the residue left in the brook system is composed largely (71 per cent) of male trout. The number of sea trout migrating from the main river is apparently too small to affect the sex ratio of those remaining.

Effect of Temperature on the Migration of Sea Trout

White (1941) has shown that the seaward migration of trout is related to the temperature of the water. He states, "Thus it seems that low temperature, and particularly a drop in temperature, not only retards the tendency to migrate down stream but causes a reversal of the movement among fish which have already started on the downstream migration". The writer has estimated from White' figure 2 that from April 17 to 28, 1940, when the water temperature varied between 0°C. and 5°C., only 142 trout moved downstream and of these 36 (25 per cent) reversed, whereas from April 29 to May 11, 1940, with the water temperature varying from 5°C. to 11°C., over 700 trout descended with only 6 reversing. It would appear from White's work that if migrating trout encountered bodies of cold water their tendency to migrate would be inhibited. In this connection, it is of interest to consider the number, size and depth of the lakes on Mill Brook and the main river.

The Character of the Lakes on Mill Brook and the Main River

Of the three lakes on the Mill Brook system, the largest is Mill Lake (68 acres), an extremely shallow lake with a maximum depth of 6 feet except for a small area about 100 feet in diameter at the head of the lake where the maximum depth is 10 feet. This lake becomes warm in summer (24.3°C. surface August 3, 1942) and being exposed to the wind the water in the main body of the lake becomes almost homothermous. During summer the lake is virtually barren of trout except for a concentration of sea trout in the small, relatively cool section at the head of the lake. Second Lake is considerably smaller (15 acres) but otherwise similar in character to Mill Lake. The maximum depth of Johnny Smith Lake (45 acres) is not known, but it is reported to be considerably deeper than Mill Lake. This lake, unlike Mill or Second Lakes, is reported to support a good population of large trout throughout the year, but few, if any, of these migrate to the sea. Elson, who operated a trap on Johnny

Smith Brook from 1941 to 1943, reported (personal communication) the capture of only 22, 31 and 7 descending trout in the three years, respectively, all of which quite possibly were produced in the brook itself.

In contrast to Mill Brook, the main river has about 40 lakes, eight of which are larger than Mill Lake and many of the others appear to be deeper and cooler. Only a few soundings have been taken in any of these lakes but a depth of 18 feet has been recorded for Bear Lake, 30 feet for Kindervater Lake and 23 feet for Boggy Lake. On June 27, 1943, the surface temperature of Bear Lake was 19.0°C. and the temperature at 18 feet 15.0°C. On July 17, 1943, the surface temperature of Kindervater Lake was 24.0°C. and the temperature at 30 feet 11.5°C. These three lakes, together with many others in this system, are reported by anglers to support good populations of trout throughout the year.

The evidence available suggests that in the main river system the trout descend to the lakes where the majority remain throughout the summer, whereas in Mill Brook, with a scarcity of deep, cool lakes, a higher proportion of the trout migrate to the sea.

Failure of Sea Trout to Migrate

There is some evidence to indicate that sea trout do not necessarily migrate to the sea every year. Of the 62 trout taken in Mill Brook above Mill Lake when the sea trout were supposedly absent, seven had been marked by the removal of the adipose fin. These trout had, therefore, at some previous date descended through the trap at the mouth of Mill Brook where they had been marked as sea trout. These marked trout were dark in colour and indistinguishable from freshwater trout at the time of capture. The fact that these trout moved through the Mill Brook trap does not prove that they actually reached salt water, although the scales of some suggested sea growth during the summer prior to their capture.

Further evidence of sea trout failing to migrate is afforded by the capture of 21 comparatively large (over 250 mm. total length) trout just below the dam at Round Lake, from May 20 to 30, 1941. These trout which had apparently spawned the previous fall were indistinguishable in coloration and general appearance from sea trout kelts. The presence of wide, even circuli on the scales indicated that some of these trout had migrated to the sea the previous spring. At the time these trout were caught, the descent of sea trout, particularly the larger individuals, was virtually complete and it is unlikely that these fish would have migrated to the sea in 1941.

On the basis of their migratory behaviour there appears to be little reason to consider sea trout hereditarily distinct from freshwater trout. Where trout grow slowly, as in First Fork Brook, Bocabec Brook and some of the smaller Moser River brooks, and mature at a small size, they fail to migrate extensively. Where growth is faster, the young trout descend from the spawning and rearing areas until they reach suitable conditions. The fact that the first suitable body of water some trout reach in their migratory movements is the sea rather than a sufficiently deep cool lake does not indicate hereditary differences in the trout.

SUMMARY

1. Anadromous and freshwater populations of *Salvelinus fontinalis* have been compared in an attempt to determine the taxonomic relationship of the sea trout and the typical brook trout.

2. Fresh-run Moser River sea trout differ strikingly in coloration from Moser River freshwater trout. After their return to the river sea trout gradually lose their typical sea coloration and by August and September are indistinguishable in coloration from freshwater trout. It is concluded that Moser River sea trout and freshwater trout do not differ hereditarily in colour.

3. Flesh colour varies directly with size but in general fresh-run sea trout have flesh of a deeper colour than most Moser River freshwater trout of comparable size. Trout from two Moser River lakes, however, had more intensely coloured flesh than fresh-run sea trout. The flesh colour of sea trout diminishes after they return to freshwater and by August and September their flesh was lighter in colour than that of freshwater trout of comparable size taken in May and June. The differences in flesh colour related to size, habitat and diet are so great as to make it impossible to recognize hereditary differences if such exist.

4. Freshwater trout reared to hatching at 5.5°C. had larger head parts, deeper and wider bodies and longer fins than those of common parentage reared at 0.9°C.

5. Moser River fresh-run sea trout generally differed from Moser River freshwater trout in having smaller head parts, shorter fins and more terete bodies. These differences were evident in both sexes but were more striking in male trout.

6. When Moser River sea trout taken one to two months after their return to freshwater were compared with Moser River freshwater trout, the differences in body form were greatly reduced, particularly when female trout were compared.

7. The average percentage difference in body form between Moser River male fresh-run sea trout and Moser River male freshwater trout was less than that between two lots of trout of common parentage reared at different temperatures.

8. Differential development of the secondary sexual characteristics will account for most, if not all, of the differences in body form between Moser River sea and freshwater trout.

9. The progeny of sea trout from Ellerslie Brook, Prince Edward Island, and the progeny of freshwater trout from Eliot River, Prince Edward Island, reared under the same conditions differed much less in body form than did two lots of trout of common parentage reared at different temperatures. They also differed much less in body form than four discrete populations of small freshwater trout.

10. Small freshwater trout from four rather widely separated brooks differed in body form more than sea and freshwater trout from the Moser River system.

11. Trout reared at 5.5°C. had more pectoral rays, dorsal rays and branchiostegals but fewer scale rows and anal rays than those reared at 0.9°C.

12. Sea trout and freshwater trout from the same river system did not differ significantly in any of the meristic structures counted.

13. The weight-length regression lines for sea trout and freshwater trout differed significantly in slope. Fresh-run sea trout averaged heavier than freshwater trout but sea trout taken one to two months later averaged lighter. These differences are related to differences in spawning and feeding habits.

14. Moser River sea trout grow more rapidly during the year in which they first migrate to the sea, but in subsequent years their annual growth is not appreciably greater than Moser River freshwater trout. Trout from four small, cool brooks grow slower than either of the above populations.

15. Resistance of freshwater trout to full sea water increases with size in immature trout but large ripe trout were, on the average, less resistant than was to be expected from their size. Since one freshwater trout survived the sudden transfer from freshwater to full sea water (30‰) for 15 days it appears that some freshwater trout could survive typical sea trout migrations.

16. A small branch of Moser River produced half as many sea trout as the much larger main river. Evidence on sex ratios and on the number and sizes of trout remaining in fresh water indicate that a higher proportion of the trout in this small branch migrate to the sea. The greater tendency for trout to run to the sea from the brook is related to the relative scarcity of deep, cool lakes on the brook system. No evidence was obtained to indicate that sea trout and freshwater trout differ hereditarily in migratory behaviour.

17. On the basis of the evidence available it is concluded that the sea trout and freshwater trout of the Moser River system constitute one taxonomic unit.

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APPENDIX

TABLE XIII. Average sizes of body parts of trout reared to hatching at different temperatures. Groups of 5 fish. All measurements in millimetres.

SL	Sn	E	PO	UJ	D	W	DH	AH	PL	VL
A-lot, reared at 5.5°C.										
84.4	5.9	6.1	11.0	12.4	18.0	14.0	11.9	11.0	13.3	11.4
91.4	6.5	6.5	12.1	13.5	20.1	15.1	13.3	12.7	14.6	12.8
94.4	6.8	6.7	12.1	13.9	20.5	15.6	13.0	13.1	14.8	12.9
96.2	6.7	6.7	12.6	14.3	20.5	16.1	13.6	13.2	15.2	13.1
97.8	7.0	6.7	12.6	14.2	21.2	16.6	13.3	13.2	14.8	13.1
99.4	7.0	6.9	12.7	14.2	21.3	16.6	14.0	13.5	15.2	13.6
100.4	7.2	6.8	13.0	14.5	21.7	16.8	13.9	13.7	15.4	13.4
101.3	7.5	7.0	13.1	15.0	22.4	17.2	14.0	13.8	16.0	13.8
104.3	7.5	7.0	13.4	15.5	23.5	18.1	14.1	13.9	15.8	14.1
110.4	8.3	7.1	14.3	16.5	24.6	18.9	15.4	15.1	16.6	14.9
B-lot, reared at 0.9°C.										
71.9	5.0	5.0	9.3	10.0	14.2	11.3	10.2	8.7	11.6	9.5
83.1	5.9	5.5	10.8	11.5	16.5	13.3	11.3	9.3	13.1	10.7
85.6	6.0	5.5	11.0	11.8	17.2	13.4	11.5	10.2	12.8	10.9
88.6	6.2	5.5	11.4	12.4	17.1	13.8	12.0	11.0	13.7	11.3
92.0	6.3	5.6	11.8	12.3	18.1	14.4	12.2	10.8	11.9	11.7
96.0	6.7	5.9	12.0	13.2	19.1	15.1	12.8	11.5	14.3	11.9
98.8	6.8	5.9	12.4	13.4	19.2	15.5	13.0	12.0	14.7	12.3
102.1*	7.0	5.9	12.5	13.8	19.7	16.0	13.0	12.7	15.0	12.6
109.0*	7.7	6.0	13.8	14.9	21.2	17.1	14.2	12.5	15.9	13.7

*Six specimens each.

TABLE XIV. Average sizes of body parts of Moser River freshwater trout. Groups of 10 fish. All measurements in millimetres.

SL	Sn	E	PO	UJ	D	W	DH	AH	PL	VL
Males										
152	10.0	8.7	20.3	22.7	35.7	20.2	19.7	20.0	24.0	19.3
160	10.5	9.2	21.2	23.5	36.2	20.0	20.3	21.5	25.6	20.2
168	11.0	9.3	22.5	24.9	38.2	20.8	20.2	20.3	25.7	20.4
177	12.0	9.8	24.0	27.2	39.8	21.7	22.6	22.8	27.9	21.8
184	12.9	10.4	24.9	28.7	42.3	23.6	24.3	23.9	29.9	23.2
191	13.3	10.7	25.9	29.9	43.0	22.9	24.7	25.5	30.7	24.4
197	13.8	11.4	26.5	31.2	44.8	24.3	25.5	25.5	32.1	25.7
206	14.2	11.4	27.5	32.5	46.1	24.7	26.7	26.9	34.3	26.7
222	16.0	12.0	30.4	35.6	50.3	26.8	28.5	28.3	37.1	28.1
260	19.0	13.2	35.0	41.7	60.2	31.2	33.2	33.7	42.5	33.7
Females										
157	10.1	8.8	19.8	21.6	34.4	21.3	19.8	20.4	24.0	19.1
164	10.0	9.1	20.9	22.1	36.4	20.4	20.1	20.8	24.6	19.2
170	10.3	9.3	21.5	22.8	37.5	21.6	20.6	20.4	25.6	19.8
182	11.2	9.8	23.1	25.1	39.8	23.1	21.9	22.9	27.4	21.2
190	11.9	10.3	24.4	26.4	41.2	23.5	22.4	23.5	29.2	22.5
206	13.2	10.9	26.7	29.2	43.6	25.1	25.2	25.4	31.7	25.0
222	14.2	11.5	28.9	30.3	47.8	26.4	26.4	27.3	33.9	25.9
248	16.6	12.7	32.4	34.9	52.4	29.5	28.7	30.3	37.9	28.8
280*	19.2	13.5	36.5	39.8	61.6	33.6	32.7	34.6	42.8	33.1

*Four specimens.

TABLE XV. Average sizes of body parts of Moser River fresh-run sea trout. Groups of 10 fish. All measurements in millimetres.

SL	Sn	E	PO	UJ	D	W	SL	DH	AH	PL	VL
Males											
176	11.2	9.2	22.7	23.7	37.0	22.5	184	22.0	22.2	26.2	20.8
204	13.4	10.2	26.6	27.7	43.2	25.6	208	25.1	24.9	30.2	23.8
233	15.8	11.3	30.4	33.4	55.9	29.3	276	31.2	31.4	39.2	30.4
324	23.3	13.9	41.7	47.1	78.6	41.9	372[1]	40.5	42.4	53.9	41.5
Females											
170	10.4	9.1	21.9	22.1	36.6	22.1	171	19.6	20.4	24.3	18.8
186	11.4	9.3	23.7	24.2	39.5	23.8	189	21.8	22.0	27.0	21.1
199	12.1	9.8	25.2	25.6	41.8	25.0	204	23.6	23.8	28.4	22.2
210	12.9	10.1	27.3	26.6	44.8	26.4	222	25.2	25.2	30.9	24.2
231	14.2	10.7	29.1	29.0	51.0	28.9	258	27.8	28.4	34.4	26.9
256	16.4	11.4	31.7	33.1	59.1	32.3	330[3]	36.6	39.0	47.8	36.2
288	18.1	12.7	35.7	37.1	66.6	36.4					
361[2]	23.7	15.3	46.5	49.5	89.2	48.8					

[1]Four specimens [2]Six specimens. [3]Eleven specimens.

TABLE XVI. Average sizes of body parts of August and September Moser River sea trout. Groups of 10 fish. All measurements in millimetres.

SL	Sn	E	PO	UJ	D	W	SL	DH	AH	PL	VL
Males											
174	11.6	9.7	23.4	25.1	36.5	21.1	174	22.6	23.3	27.6	21.5
189	13.0	9.8	25.5	27.1	40.6	22.1	192	24.7	24.7	30.7	23.9
201	13.4	10.6	27.4	28.5	42.9	23.0	211	26.4	26.4	33.2	25.6
214	14.6	10.8	28.9	30.4	44.9	24.8	288[2]	33.9	35.8	46.3	34.0
280[1]	21.7	13.0	37.6	43.7	65.0	33.2					
Females											
165	10.2	9.3	21.8	22.5	35.0	20.2	165	21.1	21.2	26.1	20.1
178	11.1	9.6	23.9	23.7	37.4	21.0	178	21.6	22.3	27.2	21.0
187	11.9	10.1	24.6	25.0	39.3	21.6	192	23.6	23.6	29.0	22.8
193	12.3	10.2	25.6	25.7	40.5	22.8	201	23.7	23.9	29.7	22.9
198	12.3	10.0	25.5	26.0	41.8	24.0	214	25.7	26.0	32.1	24.8
208	13.3	10.5	27.2	27.7	45.2	24.5	224	27.0	27.1	33.9	25.9
214	13.7	10.7	28.0	28.6	44.9	26.2	246	29.1	29.9	36.8	28.4
220	13.8	10.9	29.0	28.5	47.4	28.7	274	32.0	33.0	42.0	32.2
229	15.0	11.3	30.0	30.8	49.5	27.4	318[4]	37.2	39.2	49.2	38.5
242	15.8	11.4	31.6	32.0	52.8	28.5					
257	16.7	12.2	33.3	34.3	55.6	32.3					
291[3]	19.2	13.0	38.4	39.0	65.3	37.2					

[1]Eight specimens. [2]Six specimens. [3]Nine specimens. [4]Two specimens.

TABLE XVII. Average sizes of body parts of Ellerslie Brook and Eliot River fingerling trout reared under the same conditions. Groups of 5 fish. All measurements in millimetres.

SL	Sn	E	PO	UJ	D	W	AH	PL	VL
				Ellerslie Brook					
37.9	2.7	3.2	5.4	5.1	8.9	6.1	7.4	7.0	5.6
40.4	2.9	3.3	6.0	5.4	9.4	6.4	7.9	7.5	6.3
42.3	2.9	3.2	6.1	5.6	9.4	6.4	8.1	7.8	6.4
44.0	3.0	3.5	6.2	6.1	10.3	7.1	8.3	8.1	6.7
46.8	3.2	3.6	6.9	6.1	10.8	7.4	8.7	8.4	6.9
49.7	3.3	3.8	7.2	6.5	11.2	7.5	9.2	8.7	7.5
54.6	3.8	4.0	7.6	7.2	12.6	8.7	9.9	9.5	8.1
				Eliot River					
41.6	2.9	3.5	5.9	5.5	9.4	6.5	8.0	7.4	6.1
44.3	3.0	3.6	6.4	5.8	10.2	7.2	8.8	8.3	6.9
46.7	3.0	3.7	6.9	6.3	11.1	7.7	9.6	8.7	7.2
49.1	3.3	3.8	7.1	6.4	11.2	7.6	9.4	8.5	7.2
50.7	3.5	3.9	7.5	6.5	11.4	7.7	9.5	9.0	7.6
53.2	3.6	3.9	7.8	7.0	12.2	8.7	10.4	9.5	8.0
58.8	4.0	4.0	8.6	7.7	13.4	9.4	10.8	10.2	8.6

TABLE XVIII. Average sizes of body parts of male and female freshwater trout from Bocabec Brook, Charlotte Co., N.B., and First Fork Brook, Margaree River, N.S. Groups of 4 or 5 fish. All measurements in millimetres.

SL	*n*	Sn	E	PO	UJ	D	W	DH	AH	PL	VL
					Bocabec Brook						
Males											
80.0	4	6.0	6.1	11.1	13.4	18.9	12.4	14.0	12.9	15.5	11.9
90.0	4	7.0	6.8	12.2	15.7	22.0	14.2	14.9	14.9	17.4	13.4
108.0	4	8.7	7.4	14.8	19.5	26.1	16.5	17.0	17.4	20.5	16.2
124.2	4	10.9	8.6	18.6	24.0	31.5	18.6	20.6	20.6	23.8	18.8
Females											
73.5	4	5.3	5.5	9.8	11.6	17.1	11.6	12.4	11.6	14.2	11.1
92.4	5	6.4	6.5	12.1	14.7	21.2	14.7	14.9	15.2	17.2	13.8
114.0	5	8.7	8.0	15.3	18.9	27.0	19.8	16.5	18.4	20.4	16.0
					First Fork Brook						
Males											
104.5	4	6.4	6.4	13.2	14.8	22.0	13.6	14.6	14.9	17.4	14.1
114.0	4	7.1	6.8	13.7	16.2	25.5	14.3	15.9	15.7	19.4	15.6
129.6	5	8.8	7.5	16.4	19.5	29.0	17.0	17.5	18.3	21.5	17.5
152.0	5	9.5	8.4	19.3	23.9	33.7	19.0	20.2	21.0	25.8	20.8
Females											
103.8	5	6.2	6.3	13.0	14.1	22.6	12.8	14.3	14.4	17.1	13.6
110.2	5	6.4	6.6	13.1	14.9	24.1	14.0	14.6	14.7	18.0	14.3
125.0	5	7.6	7.5	15.2	17.2	29.2	15.6	16.3	17.5	20.6	16.1
137.8	5	8.6	8.2	17.6	20.2	31.0	17.7	17.4	18.8	22.5	17.5
147.6	5	8.8	8.3	18.7	21.1	31.6	18.6	19.6	22.5	24.7	19.5

TABLE XIX. Average sizes of body parts of male and female freshwater trout from Rocky Brook, Shubenacadie Lake, N.S., and Bezanson's Brook, Moser River, N.S. Groups of 4 or 5 fish. All measurements in millimetres.

SL	n	Sn	E	PO	UJ	D	W	DH	AH	PL	VL
					Rocky Brook						
Males											
47.6	5	3.1	3.9	6.6	7.0	11.0	7.4	8.0	7.4	9.0	7.4
50.8	4	3.6	4.1	7.0	7.2	11.6	7.3	8.3	7.9	9.8	8.1
95.5	4	6.7	6.8	12.7	11.9	20.0	14.3	14.4	13.4	16.8	13.0
113.2	4	7.9	7.1	15.8	17.6	25.8	16.2	16.6	16.4	19.7	15.3
Females											
41.2	5	2.8	3.5	5.5	5.7	9.0	5.6	6.7	6.1	7.5	6.0
46.2	4	3.1	3.9	6.4	6.6	10.4	6.5	7.4	6.9	8.8	7.0
49.2	4	3.2	4.0	6.9	7.2	11.4	7.3	8.4	7.8	9.3	7.6
54.8	4	3.7	4.1	7.4	8.0	12.6	8.3	8.8	8.6	10.4	8.7
111.2	4	7.8	7.2	15.0	16.9	24.2	16.1	15.6	15.7	18.4	14.8
172.2	4	12.4	9.4	23.0	26.2	38.0	28.4	23.6	24.2	28.0	22.5
					Bezanson's Brook						
Males											
47.2	5	3.0	4.0	6.6	6.8	10.8	7.1	8.0	7.8	9.2	7.3
56.8	4	3.9	4.4	7.8	8.1	13.1	8.2	9.3	10.0	11.2	9.4
126.8	4	9.3	8.0	18.9	21.6	26.8	18.5	18.0	17.6	22.6	17.6
Females											
52.0	5	3.2	4.0	7.2	7.3	12.1	7.0	9.0	8.6	10.0	8.2
57.2	5	3.6	4.3	7.4	7.8	13.0	7.9	9.9	9.5	10.7	9.0
98.5	4	6.7	6.4	13.3	14.5	19.9	14.8	14.4	14.2	17.0	12.9
124.0	4	8.7	8.2	17.0	18.8	27.4	17.6	17.7	17.6	21.2	17.2

TABLE XX. Specimens available for study.

MOSER RIVER, NOVA SCOTIA, AND VICINITY

Sea Trout

SMOLTS 2♂, 14♀, 116 to 180 mm. standard length. Removed from Mill Brook trap May 21, 1939—5; and May 17 to 28, 1941—11.

TROUT CAUGHT IN THE SEA. 6♂, 15♀, 204 to 370 mm. SL. Caught by angling from shore at Harrigan—2; Ecum Secum—18; and Camp Cove—1. May 18, 1941—2; June 20 to 29, 1941—13; June 21, 1942—4; and July 5, 1942—2.

FRESH-RUN TROUT. 66♂, 164♀, 145 to 428 mm. SL. Caught by angling—192; seining—30; and trapping—8: in Moser River—193; Smith Brook—34; and Moosehead Brook—3. Collected July 16, 1939—2; July 13 to 30, 1940—42; June 20 to 28, 1941—14; July 2 to 31, 1941—169; Aug. 2 to 4, 1941—2; and July 2, 1943—1.

AUGUST AND SEPTEMBER SEA TROUT. 48♂, 120♀, 160 to 327 mm. SL. Caught by angling—158; and trapping—10: in Halfway Brook—1; Eel Brook—2; Moosehead Brook—9; Smith Brook—18; Mill Brook—21; and Moser River—117. Collected Sept. 4 to 13, 1939—48; Aug. 4 to 31, 1940—78; Sept 1 to 9, 1940—26; Aug. 3 to 19, 1941—13; and Sept. 10, 1941—3.

TABLE XX (*continued*).

Freshwater Trout

100♂, 84♀, 150 to 305 mm. SL. All caught by angling: in Jewer's Cove Brook—3; Moosehead Brook—12; Smith Brook—19; Mill Brook—62; and Moser River—88. Collected May 20 to 30, 1941—47; and June 7 to 26, 1941—137.

Small Trout

76♂, 61♀, 37 to 149 mm. SL. This group principally trout below migratory size which could be the progeny of either sea trout or freshwater trout. Those taken May 20 to June 26, 1941, combined with freshwater trout for growth studies. Otherwise not used for comparisons of sea and freshwater trout. Seined or taken by angling: in Eel Brook—1; Moosehead Brook—1; Smith Brook—24; Mill Brook—26; and other Moser River brooks—85. Collected June 15, 1940—6; July 22 to 29, 1940—15; Aug. 7 to 29, 1940—30; Sept. 3 to 7, 1940—15; May 20 to 29, 1941—9; June 2 to 26, 1941—38; July 31, 1941—5; Aug. 7 to 30, 1941—15; and Sept. 2 to 7, 1941—4.

"Doubtfuls"

83♂, 65♀, 125 to 314 mm. SL. Principally trout above migratory size which could not be classified as sea or freshwater trout. Caught by angling in Eel Brook—4; Halfway Brook—5; Moosehead Brook—8; Smith Brook—37; Mill Brook—42; and Moser River—52. Collected July 20 to 30, 1940—18; Aug. 6 to 31, 1940—45; Sept. 1 to 9, 1940—52; July 10 to 26, 1941—17; Aug. 6 to 27, 1941—15; and Sept. 5, 1941—1.

Bezanson's Brook

13♂, 18♀, 41 to 156 mm. SL. Seined Aug. 2 to 7, 1940—27; and Aug. 10, 1941—4. This group selected from Moser River collection as example of slow-growing trout from a small, cool brook.

FIRST FORK BROOK, MARGAREE RIVER, NOVA SCOTIA

18♂, 25♀, 94 to 168 mm. SL. Freshwater trout angled July 1, 1941.

ROCKY BROOK, SHUBENACADIE LAKE, NOVA SCOTIA

17♂, 25♀, 39 to 192 mm. SL. Freshwater trout seined Aug. 10, 1940.

BOCABEC BROOK, CHARLOTTE CO., NEW BRUNSWICK

16♂, 14♀, 57 to 132 mm. SL. Freshwater trout angled Sept. 23, 1940.

LAKE UTOPIA, CHARLOTTE CO., NEW BRUNSWICK

A-lot. 27♂, 23♀, 80 to 116 mm. SL. Eggs obtained from pair of Lake Utopia trout Nov. 22, 1939, and maintained at 5.5°C. until hatching completed (Feb. 28, 1940). Killed for study Aug. 19, 1941.

B-lot. 26♂, 21♀, 59 to 114 mm. SL. Eggs obtained from same pair of Lake Utopia trout Nov. 22, 1939, and maintained at 0.9°C. until hatching completed (June 28, 1940). Killed for study Nov. 12, 1941.

ELLERSLIE BROOK, PRINCE EDWARD ISLAND

35 trout not sexed, 36 to 58 mm. SL. Eggs obtained from known sea-run Ellerslie trout in fall of 1947. Eggs hatched and reared at Southport and Cardigan, P.E.I. Trout killed for study Sept. 1, 1948.

ELIOT RIVER, PRINCE EDWARD ISLAND

35 trout not sexed, 40 to 62 mm. SL. Eggs obtained in fall of 1947 from trout from Eliot River, P.E.I., which has been inaccessible to sea trout for at least 20 years because of a head-of-tide dam. Eggs hatched and reared at Southport and Cardigan, P.E.I., under same conditions as Ellerslie stock. Killed for study Sept. 1, 1948.

The Benthos of Cultus Lake[1]

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ABSTRACT

The bottom fauna of the deep water of Cultus Lake averages about 530 grams per square meter, dry weight, during the period January-May, and 720 in June-September. This is divided almost equally between Chironomidae and Oligochaeta, other organisms being negligible. The midges are extensively used as food by trout and other fishes during their season of emergence in winter and spring. The spatial distribution of the organisms is usually close to random as between samples 500 square centimeters in area, the only exception being that the oligochaetes were strongly bunched in winter.

INTRODUCTION

In the year 1932 several series of dredgings were made in Cultus Lake, British Columbia, as part of a general limnological study aimed at identifying factors which might be controlling sockeye salmon production. It soon became apparent that sockeye rarely ate bottom organisms, so the work was discontinued before any really comprehensive sampling had been accomplished, particularly in shallow water. It seems profitable to put the results on record, however, for what value they have in comparative studies.

Cultus Lake (Figure 1) is of 626 hectares extent, up to 42 meters deep, and with precipitous shores, so that the average depth is 32 meters. More than four-fifths of the bottom of the lake may be considered to be in the "profundal" life zone, below the 20-meter contour. Classified on the basis of hypolimnial oxygen content, it falls into the oligotrophic type, for only about a third of the oxygen is removed from the water of the hypolimnion in the course of a rather long stagnation period, in summer and early autumn.

METHODS

Quantitative samples of the bottom of the lake were taken in an Ekman dredge of 500 square centimeters gape. The sediment was washed through a wire screen and two squares of bolting silk, the smallest being of mesh OXX, having 15 threads per centimeter. Most attention was given to fauna of the profundal zone, because of the large area covered by that zone, and because of the impossibility of giving adequate treatment to the more varied life at lesser depths.

SHALLOW LITTORAL ZONE

The littoral zone of Cultus Lake may conveniently be divided into a shallow and a deeper part. The shallow part extends to about 3 meters, is affected by

[1]Paper No. 7 of a series, "Factors affecting the behaviour and survival of sockeye salmon (*Oncorhynchus nerka* Walbaum) during their lacustrine existence in Cultus Lake, British Columbia".

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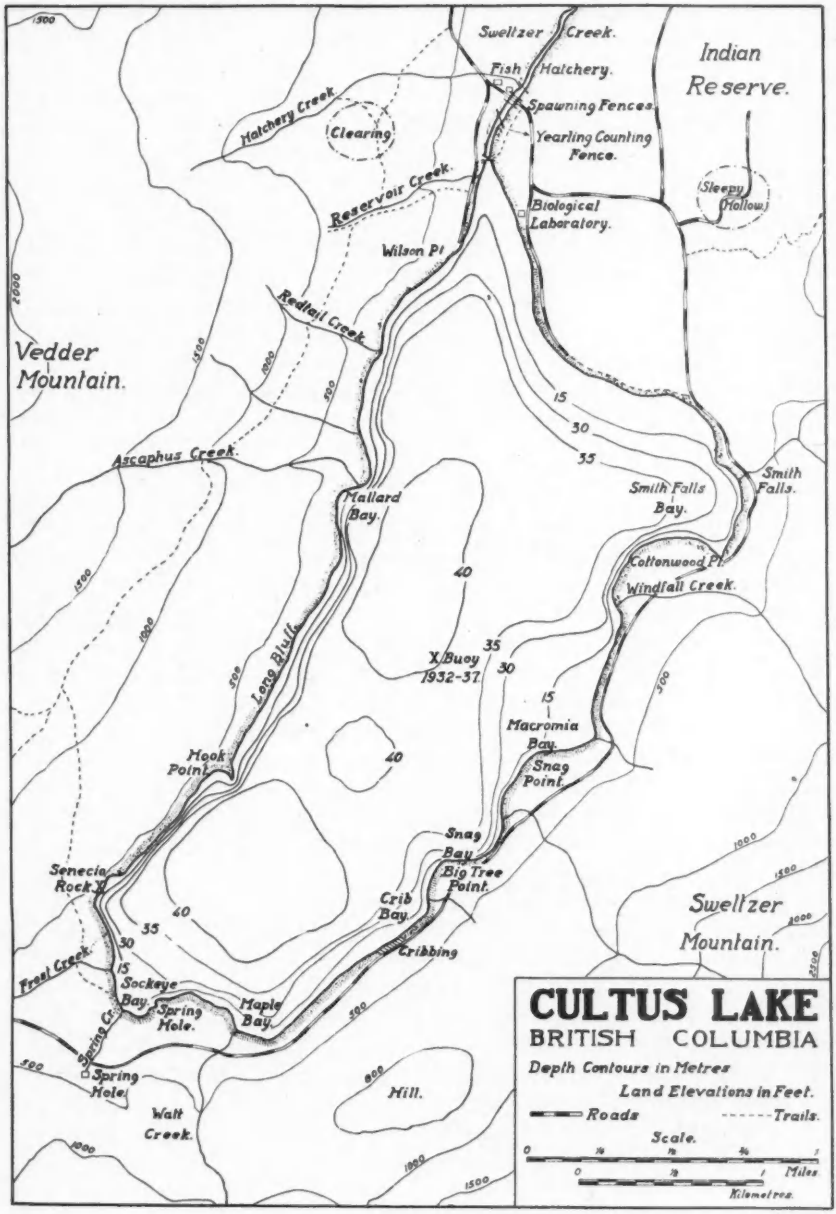

FIGURE 1. Map of Cultus Lake, British Columbia.

wave action, and for the most part lacks rooted vegetation. The principal types of bottom are as follows:

1. Bed-rock or large boulders, falling steeply away.
2. Stony, bearing in a few places beds of emergent bulrushes (*Scirpus*), horse-tails (*Equiseum*), and, rarely, cat-tails (*Typha*), at depths up to 1.5 meters. In protected locations submersed weed beds come close to shore, as does the floating-leafed *Potamogeton amplifolius*.
3. Loose wave-washed rubble, or occasionally, sand, barren of macroscopic vegetation.
4. Mud with abundant logs and woody debris, found only in the corners of the deepest bays; sometimes with sparsely-set submersed phanerogams.

The greater part of the lake has the second or stony type of shore. This is the home of a considerable fauna of Odonata, including the characteristic flat nymphs of the dragonfly *Macromia rickeri* Walker. Several damsel-flies are abundant, particularly among the *Scirpus*. It is inhabited also by many snails of the genera *Physa* and *Lymnaea*. No systematic collecting has been done in any shoreward habitat.

DEEP LITTORAL AND SUBLITTORAL ZONES

The deeper littoral zone typically is covered by a dense stand of rooted and completely submersed aquatic plants, except where the bottom is of massive rocks. It may be considered to extend to about 14 meters depth, following the common usage which sets the limit of the littoral at the base of the thermocline. The region from 14 to 20 meters may be assigned to the conventional sublittoral (extending to the limit of macroscopic vegetation), but there is little to distinguish it from the area immediately above.

A number of samples were taken in the deep littoral zone along the northern shore of the lake. These show that the bottom is there composed of gravel in its shallower parts, becoming more sandy offshore. In deeper water the bottom becomes more and more muddy, merging into the profundal ooze. In some more sheltered spots it is probable that the bottom is entirely muddy from the shallow littoral outward.

Larger rooted aquatics are often found down to about 10 meters. The northwest arm of the lake produces them most prolifically; there is also a growth in Macromia Bay, on the east side, along the north shore of Smith Falls Bay, and in scattered groups elsewhere. No detailed study of the species occurring has been made. *Chara* is probably as common as any other form. *Potamogeton amplifolius* extends to considerable depths; *P. heterophyllus* is commoner just outside the shallow littoral belt, and in the outlet creek; *P. richardsonii* is common in strictly quiet locations; *P. praelongus* has been seen in dredgings only, at 5 meters or more; a linear-leaved *Potomageton* is less common. *Ceratophyllum demersum* is common in Squawfish Bay and elsewhere, especially at depths of 8-10 meters. *Myriophyllum* is found in shallower situations as a rule; detached fragments are not infrequently observed in summer, floating in the open water of the lake. *Ranunculus aquatalis* var. *capillaceus* is one of the

scarcer forms; its flowers may be seen along Cottonwood Point. The blue-green alga *Nostoc,* which grows in masses up to 4 centimeters diameter, may perhaps be included as one of the larger aquatics. It was dredged abundantly in winter from the bottom just off the northern beach at depths of 10-20 meters, and a *Cladophora* was found in the same situation.

The fauna of the deep littoral and sublittoral region is known only from a few dredgings taken January to August, off the north shore of the lake. No estimate has been made of the quantity of animal life present, and identification has been carried only to the grosser divisions.

Porifera—*Spongilla* was found in a few instances, but is more characteristic of the littoral zone, where it grows on logs and rocks.

Polyzoa—A species of *Plumatella* was common on leaves of *Potamogeton.*

Turbellaria—Taken rarely.

Hirudinea—*Helobdella stagnalis* and a small white species were taken.

Oligochaeta—Regularly present.

Crustacea—*Hyallella azteca* was an abundant species down to about 15 meters depth. Ostracoda were abundant.

Ephemeroptera—*Callibaetis* and *Caenis* were found in the dredgings. Imagos of these and a few other genera have been taken near the lake.

Odonata—Nymphs of *Enallagma* were found down to about 5 meters depth. Walker and Ricker (1937) list the adult Odonata taken at the lake, but many of the species may be confined to the shallow littoral, or be wanderers from other waters.

Trichoptera—Larvae of Limnephilidae, Polycentropidae, Leptoceridae, *Mystacides* and Hydroptilidae were collected.

Diptera—Larvae of Chironominae and Tanypinae were common throughout the region; *Culicoides* was not uncommon.

Hydracarina—Not very common. Marshall (1929) has recorded from Cultus Lake *Piona rotunda* Kram. and *Diplodontus despiciens* Mull.

Gastropoda—The genera *Physa, Valvata, Limnaea* (s.l.), *Gryaulus* and *Helisoma* are represented in the collection.

Pelecypoda—*Pisidium* and *Musculium* were found, the former more commonly; also an undetermined Unionid, which is commoner in the shallow littoral.

PROFUNDAL ZONE

The profundal region of Cultus Lake consists of a grey ooze which contains carbonized fir needles and other plant material. Its macroscopic fauna is very limited in species. Oligochaeta are represented by one species, probably a *Tubifex. Hyalella* and *Pisidium* occur occasionally in even the deepest water. The dominant group is the Chironomidae, particularly a large red *Chironomus;* several smaller species of Chironominae and a few of Tanypinae can be distinguished. Ostracoda are abundant, but have not been considered in the present study. The mayfly *Hexagenia,* whose imagos are occasionally taken near the lake, may have its nymphs sparsely distributed in the profundal zone, though none were found.

Twenty-seven dredgings were made in the profundal ooze, at depths of 30 to 40 meters, in seven series, taken January to September, 1932. The results are presented in Table I. There appears to be no significant seasonal variation in the abundance of oligochaetes over the period studied; their egg capsules were taken in August and September. The variation in numbers of the chironomids in the dredgings indicates a definite seasonal trend; they begin to increase in June and by early autumn are about twice as common as in the spring preceding; their fate in the succeeding months is unknown. The number of large individuals of the large *Chironomus* is particularly variable. Its imagos emerge in winter, December to March, so that by early spring large larvae are scarce, having decreased from 70 per square meter in late January to only about 20 per square meter in late March. Throughout the summer they increase to the neighbourhood of 160 per square meter.

TABLE I. Profundal fauna of Cultus Lake. Average number of macroscopic organisms per square meter, determined from dredgings of 500 square centimeters each.

Date, 1932		Jan. 20	Feb. 19–22	Mar. 23	May 4	June 20	Aug. 15	Sept. 26
Number of dredgings		3	4	4	4	4	4	4
Chironominae[a]	Large	73	60	20	60	80	145	155
	Medium	67	55	75	65	135	155	125
	Small	13	105	120	115	60	180	235
	Very Small[b]	7	80	10	5	60	10	10
Tanypinae[a]	Medium	67	85	105	55	125	285	315
	Small	—	5	125	110	135	80	100
	Very small[b]	7	35	10	—	30	15	—
Total Chironomidae		240	420	460	410	620	870	940
Oligocheta	Worms	207	335	250	370	265	305	255
	Egg capsules[b]	—	—	—	—	—	95	35
Pisidium		20	—	—	—	5	—	—
Hyalella		—	—	10	25	—	—	—
Total		470	760	720	800	890	1270	1230

[a]Includes larvae and pupae.
[b]Because of their small size, these organisms may have been incompletely recovered from the dredgings.

DISTRIBUTION OF PROFUNDAL ORGANISMS

Since four dredgings were taken each month (three in January) from the profundal region, some idea of the uniformity of distribution of its organisms can be obtained by a method already outlined (Ricker, 1937c). Table II gives the χ^2 measure of the differences between dredgings taken each month, being the sum of the square of the difference of each dredging from the mean of its group, divided by that mean. Comparison of the χ^2 values with a table of the same shows only insignificant or barely significant deviations from random distribution, considering the successive dates either singly or collectively, *except* in the case of the oligochaetes. Even with them a non-random, bunched, dis-

tribution is indicated only in the three winter months. During this period, however, it is very pronounced; the variance of the observations is seven to nine times their mean, whereas with random distribution they would be equal. Evidently the worms form aggregations during the cold weather.

With that exception, the distribution of organisms in the samples is demonstrated to be sufficiently close to random to show that no considerable average differences in density can exist over the northern and central part of the lake, from which the samples were taken. Even the discrepancy noted, the bunched distribution of oligochaetes in winter, does not disprove the possibility of an effectively uniform distribution over areas larger than 500 square centimetres —say per *are*, or even per square meter, of the bottom. A comparison of the numbers of organisms at each station on successive dates does not suggest that any one station has a consistently higher number than any other. These results show that the samples can be considered as representative of the northern half of the profundal zone of the lake, and the southern half is physically similar.

TABLE II. Tests for random spatial distribution of profundal organisms. Figures tabulated are χ^2 values, associated with the number of degrees of freedom indicated in the second-last column. In the last column the value of χ^2 is given, corresponding to 5 per cent probability of accidental occurrence.

Date	Large and medium chironomines	Small chironomines	Medium tanypines	Oligochaetes	Degrees of freedom	5% point of χ^2 distribution
Jan. 20	1.1	1.0	0.9	14.8	2	6.0
Feb. 19–22	4.3	2.1	8.3	27.7	3	7.8
Mar. 23	0.6	2.3	0.6	22.9	3	7.8
May 4	8.9	7.4	5.4	4.9	3	7.8
June 20	5.6	8.0	2.4	0.2	3	7.8
Aug. 15	3.1	8.2	7.8	0.9	3	7.8
Sept. 26	0.4	6.4	4.0	2.0	3	7.8
Total	24.0	34.4	29.4	73.4	20	31.4

WEIGHT OF THE PROFUNDAL FAUNA

The dry weight of the profundal fauna was determined in rough fashion by weighing groups of representative organisms, and calculating an average unit weight for each. The organisms were taken from alcoholic solution and dried for 24 hours over calcium chloride at 20° C. Weight units used were as follows, in milligrams: chironomine larvae, large — 1.7, medium — 0.6, small — 0.2, very small — 0.05; tanypine larvae, medium, 0.3–0.5, small — 0.1; oligochaetes — 1.1, their egg capsules — 0.06; *Hyalella* — 0.5; *Pisidium* (excluding shell) — 0.2. As a check a few entire dredgings were dried, and the estimated weight differed from the true weight by at most 20 per cent.

Table III gives the calculated dry weight of the dredgings. The weights again show the increase in the chironomid fauna during summertime. The total

dry weight of the fauna averaged 530 milligrams per square meter in spring and 720 in summer (4.7 and 6.4 pounds per acre).

For comparative purposes the ratio of the dry weight of the organisms to their wet weight, when preserved in alcohol, was determined. The conversion factors averaged 6.6 for large chironomids, 9.2 for medium and small chironomids, and 8.7 for oligochaetes. These are all higher than the factor 5 used by Rawson (1934, 1939); however on the basis of a more recent study Rawson (personal communication) regards 15 per cent as a better representative ratio of dry to wet weight (factor = 6.7). Since Rawson's quantitative data on British Columbia lakes are based upon weighings of the organisms when wet, the comparisons here are made by converting our dry weights to terms of wet weight, using the above factors determined from Cultus Lake materials. Wet weights determined in this way are included in Table III.

TABLE III. Average dry weight of the profundal organisms in milligrams per square meter, with a summary in terms of wet weight. (To change to kilograms per hectare, divide by 100; to pounds per acre, by 112.)

	Jan. 20	Feb. 19–22	Mar. 23	May 4	June 20	Aug. 15	Sept. 26
Chironomidae	192	228	206	208	284	464	480
Oligochaeta	228	368	276	408	292	342	284
Other organisms	4	—	4	—	4	—	—
Total	420	600	490	620	580	810	760

	Average dry weight		Average wet weight	
	Jan.-May	June-Sept.	Jan.-May	June-Sept.
Chironomidae	208	410	1480	3480
Oligochaeta	320	306	2780	2650
Other organisms	2	1	40	2
Total	530	720	4300	6130

DISCUSSION

COMPARISON WITH OTHER LAKES

Almost the only student of the quantitative distribution of bottom organisms in lakes of the Canadian cordillera is Dr. D. S. Rawson, whose 1942 paper summarizes his work on six lakes. Since the Cultus Lake information does not include anything on the shallower regions, it is impossible to make comparisons with the whole of this series. However, in earlier papers (Rawson, 1934, 1939) the results of dredgings in two cordilleran lakes are presented in sufficient detail to permit a comparison of their summer profundal faunas with that of Cultus Lake (Table IV). The lakes in question are Paul Lake near Kamloops, and Okanagan Lake, both lying in the southern interior dry region of British Columbia.

In the three lakes of Table IV the crop of bottom organisms decreases with increasing lake size, though Paul Lake has a deeper and cooler profundal zone

than Cultus. There are also important qualitative differences between the three. These are shown in Table V, which includes also profundal dredgings made on an arm of Shuswap Lake (Clemens *et al.*, 1938), another large oligotrophic lake of the Interior. Cultus, Okanagan and Shuswap Lakes are alike in having only midges and oligochaetes in significant numbers in the profundal zone. The relative numbers of the two groups are about the same, approximately three midges to one worm, but Okanagan has only a third and Shuswap a fifth as many organisms as Cultus. Paul Lake is quite different. Chironomids are still numerous, but oligochaetes are scarce. Taking their place are numerous Sphaeriidae, many *Gammarus*, and some planarians. The total fauna is numerically less than in Cultus Lake, but the large size of the *Gammarus* makes its bulk much greater.

TABLE IV. Comparison of three British Columbia lakes. Data on Paul and Okanagan Lakes are from Rawson (1934, 1939, 1942).

	Paul	Cultus	Okanagan
Latitude	50° 45′	49° 4′	50° 0′
Elevation, meters	777	50	345
Length, kilometers	6.1	4.5	107
Average width, kilometers	0.48	1.3	3.2
Area, hectares	390	630	37000
Shore development	1.8	1.5	3.9
Maximum depth, meters	56	42	232
Mean depth, meters	34.2	32.1	69.5
Area included in 20-meter contour, hectares	286	530	27900
Average depth of profundal region, meters	45.9	36.3	89.2
Bottom temperature on August 15, °C.	4.8	5.4–6.4	4.6
Bottom oxygen on August 15, milligrams per liter	6.6	7.2–9.6	7.3
Bound carbon dioxide content, milligrams per liter	65	35	45
Wet weight of profundal fauna in summer, kilograms per hectare	109	61	9.5[a]

[a]Determined by taking the unweighted average of all dredgings (52) at 20 meters or greater depth.

TABLE V. Average numbers of bottom organisms per square meter in the profundal region of four British Columbia lakes, in summer. Data for Paul and Okanagan Lakes are from Rawson (1934, 1939); those for Shuswap Lake are from Clemens *et al.* (1931). The abundance of organisms in Paul Lake is an average weighted according to the area of the various depth zones. For the other lakes a simple average of all dredgings of 20 meters or deeper is used.

Lake	Paul	Cultus	Okanagan	Shuswap
Number of dredgings	21	12	52	4
Chironomidae	531	810	262	145
Oligochaeta	10	275	74	64
Turbellaria	27	0	0	0
Sphaeriidae	220	2	3	0
Gammarus	41	0	0	0
Others	0	0	3	5
Total	829	1087	342	214

Utilization of the Bottom Fauna

Many stomachs of Cultus Lake fish have been examined, though the results have not been published in detail (cf. Ricker, 1941). The midges, particularly pupae emerging in the spring, make up a large part of the food of trout (*Salmo clarkii*) and coho salmon (*Oncorhynchus kisutch*). Squawfish (*Ptychocheilus oregonensis*) eat considerable quantities of benthic organisms, particularly snails and insects taken inshore, though their principal food is fish. Chubs (*Mylocheilus caurinus*) and rocky mountain whitefish (*Prosopium williamsonii*) both eat bottom organisms, chiefly from the shallower parts of the lake, but neither species is common. Suckers (*Catostomus macrocheilus*) are numerous, and examination of the stomachs of a few shows bottom organisms to be their food, ingested along with much mud. The larger sculpin of the lake (*Cottus asper*) takes some benthos, but more fish; the small *Cottus aleuticus* eats midge larvae, Ostracoda and some plankton. Both sculpins serve as food for char (*Salvelinus malma*) and occasionally other salmonids, and thus transform benthic materials to usable fish food. The oligochaetes which make up about half of the standing crop (but probably not half of the annual production) of the profundal zone, appear to be very little utilized by fish. They may be important in the diet of suckers, but no other fish is known to benefit much from them, either directly or indirectly.

The fingerling sockeye salmon (*Oncorhynchus nerka*) of the lake consume practically no benthic organisms (Ricker, 1937b). Only occasionally do ostracods appear in a stomach, along with the abundant plankton. The larger "residual" sockeyes have been found to contain emerging midges, but even in them that is exceptional. The principal importance of the bottom fauna to the sockeye lies in the fact that it constitutes a reserve of "buffer" foods, to which their predacious fish enemies can turn in years when sockeye are scarce (Ricker, 1941).

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